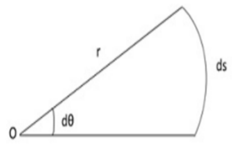
Chapter 1
Units and Measurement

1.Name the fundamental(base) quantities and units according to SI system.

BASE QUANTITY	BASE UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Thermodynamic Temperature	kelvin	K
Amount of Substance	mole	mol
Luminous Intensity	candela	cd

SUPPLEMENTARY QUANTITY	SUPPLEMENTARY UNITS	SYMBOL
Plane Angle	radian	rad
Solid Angle	steradian	sr

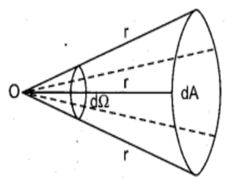
2.Define angle



$$\text{Angle} = \frac{arc}{radius}$$

$$d\theta = \frac{ds}{r}$$

3.Define solid angle



$$\text{Solid angle} = \frac{\text{Intercepted } Area}{Square\ of\ radius}$$

$$d\Omega = \frac{dA}{r^2}$$

4.Write the dimensional formulae of following derived quantities.

Area - L^2

Volume - L^3

Density - ML^{-3}

Velocity - LT^{-1}

Acceleration - LT^{-2}

Momentum - MLT^{-1}

Force - MLT^{-2}

Work or energy - ML^2T^{-2}

Power - ML^2T^{-3}

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

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

Modulus of elasticity - $ML^{-1}T^{-2}$

5.Write two physical quantities having no unit and dimension

Relative density, strain

Seema Elizabeth, MARM Govt HSS Santhipuram, Thrissur

6.Write two physical quantities that have unit but no dimension

Plane angle, solid angle, angular displacement

7.

Find the dimensional formula of Gravitational constant using equation $F = \frac{Gm_1m_2}{r^2}$

$$G = \frac{Fr^2}{m_1m_2}$$

$$[G] = \frac{[F][r^2]}{[m_1]\,[m_2]}$$

$$[G] = \frac{[MLT^{-2}][L^2]}{[M][M]}$$

$$= [MLT^{-2}]\,[L^2]\,[M^{-1}]\,[M^{-1}]$$

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

8.

Find the dimensional formula of Planck's constant using equation $\lambda = \frac{h}{mv}$

$$h = \lambda mv$$

$$[h] = [\lambda][m][v]$$

$$[h] = [L][M]\,[LT^{-1}]$$

$$[h] = [ML^2T^{-1}]$$

9.Name and state the principle used to check the correctness of an equation.

Principle of homogeneity of dimensions.

For an equation to be correct the dimensions of each terms on both sides of the equation must be the same Or

The magnitudes of physical quantities may be added or subtracted only if they have the same dimensions.

10. Write the uses of dimensional analysis

1. Checking the dimensional consistency (correctness) of equatons.
2. Deducing relation among the physical quantities.

11. Using the method of dimension check whether the equation is dimensionally correct or not

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

s= displacement
u =initial velocity
a=acceleration
t=time

$$[s] = L$$

$$[ut] = LT^{-1} \times T = L$$

$$[\tfrac{1}{2}at] = LT^{-2} \times T = LT^{-1}$$

Since the dimensions of all terms are not same the equation is not correct

12. Using the method of dimension check whether the equation is dimensionally correct or not

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

s= displacement
u =initial velocity
a=acceleration
t=time

$$[s] = L$$
$$[ut] = LT^{-1} \times T = L$$
$$[\tfrac{1}{2}at^2] = LT^{-2} \times T^2 = L$$

Since the dimensions of all terms on both sides are same the equation is dimensionally correct correct

13. Using the method of dimension check whether the equation is dimensionally correct or not

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

m=mas of th body
v= velocity of body
g=acceleration due to gravity
h=height

$$[\tfrac{1}{2}mv^2] = M\,[LT^{-1}]^2 = ML^2T^{-2}$$

$$[mgh] = M\;LT^{-2}\;L = ML^2T^{-2}$$

The dimensions of LHS and RHS are the same and hence the equation is dimensionally correct.

14.Check the dimensional correctness of the equation $E=mc^2$

$$[E] = ML^2T^{-2}$$

E=energy
m=mass
c=velocity of light

$$[mc^2] = M\,[LT^{-1}]^2 = ML^2T^{-2}$$

The dimensions of LHS and RHS are the same and hence the equation is dimensionally correct.

15.In the given equation $v = x + at$, find the dimensions of x.

(where v= velocity , a=acceleration , t=time)

$$v = x + at$$
$$[v] = [x] = [at]$$
$$[x] = [v]$$
$$[x] = LT^{-1}$$

16. In the given equatio $x = a + bt + ct^2$, find the dimensions of a,b and c.

(where x is in meters and t in seconds)

$$x = a + bt + ct^2$$
$$[x] = [a] = [bt] = [ct^2]$$

$[a] = [x]$

$[a] = L$

$[bt] = [x]$

$[b] \times T = L$

$[b] = \frac{L}{T}$

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

$[ct^2] = [x]$

$[c] \times T^2 = L$

$[c] = \frac{L}{T^2}$

$[c] = LT^{-2}$

17.The Van der waals equation of 'n' moles of a real gas is $(P+\frac{a}{V^2})(V-b)=nRT$. Where P is the pressure, V is the volume, T is absolute temperature, R is molar gas constant and a, b, c are Van der waal constants. Find the dimensional formula for a and b.

$$(P+\frac{a}{V^2})(V-b)=nRT.$$

By principle of homegeneity, the quantities with same dimensions can be added or subtracted.

$$[P] = [\frac{a}{V^2}]$$
$$[a] = [PV^2]$$
$$= ML^{-1}T^{-2} \times L^6$$
$$[a] = ML^5T^{-2}$$
$$[b] = [V]$$
$$[b] = L^3$$

18.Derive the equation for kinetic energy E of a body of mass m moving with velocity v

$$E \alpha \; m^x \; v^y$$
$$E = k\, m^x v^y \longrightarrow (1)$$

Writing the dimensions on both sides,

$$M L^2 T^{-2} = M^x (LT^{-1})^y$$
$$M^1L^2 \; T^{-2} = M^x \; L^y \; T^{-y}$$

equating the dimensions on both sides,

$$x = 1$$
$$y = 2$$

Substituting in eq (1)

$$E = k\, m^1 v^2$$
$$\boxed{E = k\, mv^2}$$

19.derive the expression for period of oscillations of a simple pendulum using the method of dimensions

$$T \propto m^x \; l^y \; g^z$$
$$T = k\, m^x l^y g^z \longrightarrow (1)$$

Writing the dimensions on both sides,

$$M^0L^0T^1 = M^x \; L^y \; (LT^{-2})^z$$
$$M^0L^0T^1 = M^x \; L^y \; L^z \; T^{-2z}$$
$$M^0L^0T^1 = M^x \; L^{y+z} \; T^{-2z}$$

equating the dimensions on both sides,

$$x = 0$$
$$y + z = 0$$
$$-2z = 1 \quad z = \frac{-1}{2}$$
$$y + \frac{-1}{2} = 0 \quad y = \frac{1}{2}$$
$$\boxed{T = k m^0 \, l^{1/2} g^{-1/2}}$$
$$T = k\frac{l^{1/2}}{g^{1/2}}$$
$$T = k\sqrt{\frac{l}{g}}$$

20.Write any two limitations of dimensional analysis.

1) Dimensional analysis check only the dimensional correctness of an equation, but not the exact correctness.
2) The dimensionless constants cannot be obtained by this method.
3) We cannot deduce a relation, if a physical quantity depends on more than three physical quantities.
4) The method cannot be considered to derive equations involving more than one term
5) A formula containing trigonometric , exponential and logarithmic function can not be derived from it.
6) It does not distinguish between the physical quantities having same dimensions.

21.What do you mean by significant figures?

The reliable digits plus the first uncertain digit in a measurement are known as significant digits or significant figures.

22.Find the number of significant figures in following numbers

0.02380 - 4
23.08 - 4
23.80 - 4
2380 - 3
43.00 - 4
4300 - 2
4.700×10^{2} - 4
4.700×10^{-3} - 4

23.If mass of an object is measured to be, 4.237 g (four significant figures) and its volume is measured to be 2.51cm3(3 significant figures), then find its density in appropriate significant figures.

$$\text{Density} = \frac{mass}{volume} = \frac{4.237\ g}{2.51 cm^3} = 1.688047$$

As per rule the final result should be rounded to 3 significant figures .

So the answer is 1.69 g/ cm^3

24.Find the sum of the numbers 436.32 g, 227.2 g and 0.301 g to appropriate significant figures.

436.32 g + (2 decimal places)
227.2 g + (1 decimal place)
0.301 g (3 decimal places)

663.821 g

As per rule ,the final result should be rounded to 1 decimal place.

So the answer 663.8 g

Chapter 2
Motion in a Straight Line

1.Define instantaneous velocity?
The velocity at an instant is called instantaneous velocity.

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

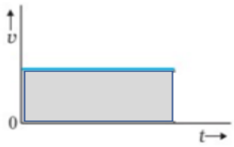
$$\mathbf{v = \frac{dx}{dt}}$$

2.When does the average velocity become equal to instantaneous velocity?
When the time interval $\Delta t \to 0$,the average velocity becomes equal to instantaneous velocity.

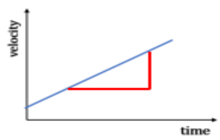
$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

3.The speedometer of a vehicle shows ....
Instantaneous speed.

4. The area under velocity -time graph gives ----- ---
Displacement



5. The slope of velocity-time graph gives ----------- --
Acceleration



6. Define average accelaration
The average acceleration over a time interval is defined as the ratio of change in velocity to the time interval.

$$\vec{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

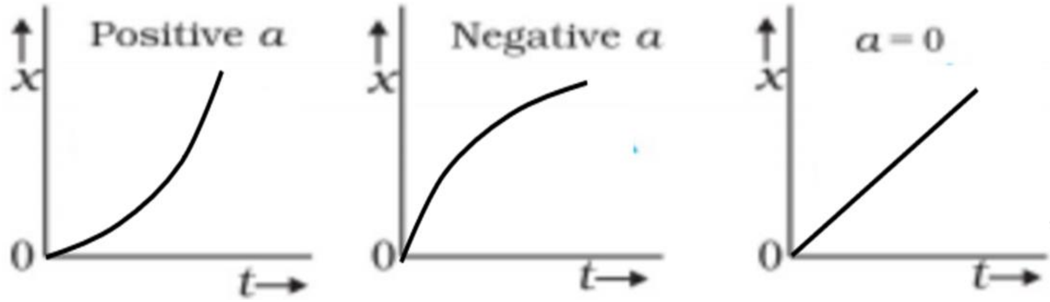
7.Define instantaneous acceleration.
The acceleration of a particle at any instant of its motion is called instantaneous acceleration.

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

$$a = \frac{dv}{dt}$$

8.Draw the position- time graph of an object moving with

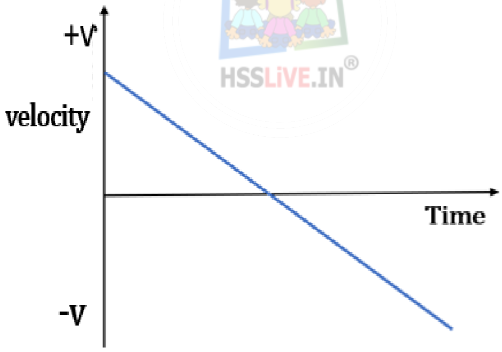
(a)positive acceleration (b) negative acceleration c)zero acceleration



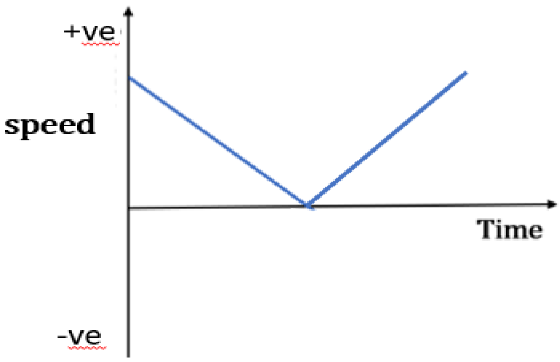
9. Draw the velocity- time graph of an object moving with

(a) uniform positive acceleration (b) uniform negative acceleration

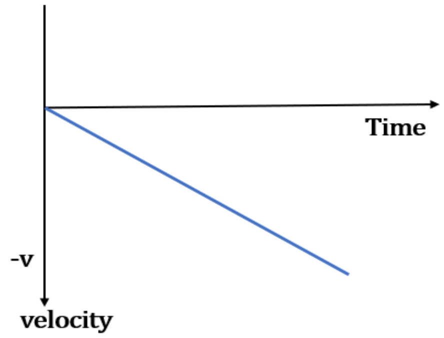
10.Draw the velocity- time graph of a stone thown vertiaccly upwrds and comes back.



11.Draw the speed- time graph of a stone thown vertiaccly upwrds and comes back.



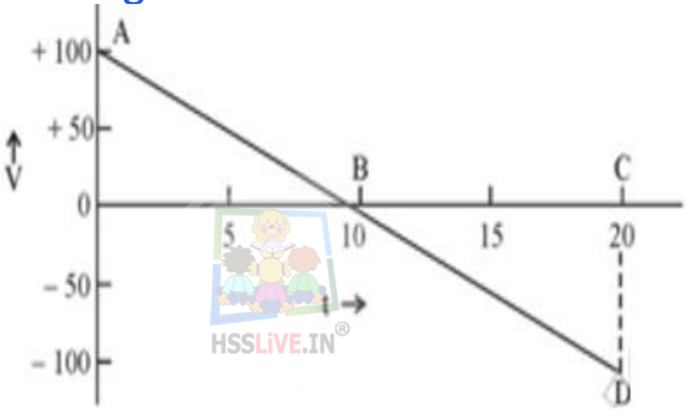
12. Draw the velocity-time graph of a freely falling body.(A stone vertically falling downwards)



13. Is it possible for a body to have zero velocity with a nonzero acceleration. Give an example.

Yes. When a body is thrown upwards ,at the highest point of projection, its velocity is zero , but it has an acceleration.

14.The velocity -time graph of a ball thrown vertically upward with an initial velocity is shown in figure.



a)What is themagnitude of initial velocity of ball?

b)Calculate the distance travelled by the ball during 20seconds from the grah.

c) Calculate the acceleration of the ball from the graph

a)Initial velocity=100m/s

b)Distance travelled = area of graph

$$=\frac{1}{2} b_1h_1 + \frac{1}{2} b_2h_2$$

$$=\frac{1}{2} x10 \text{ x } 100 + \frac{1}{2} \text{ x } 10 \text{ x}100$$

$$=1000\text{m}$$

c) Acceleration = slope

$$= \frac{v_2-v_1}{t_2-t_1} = \frac{0-100}{10-0} = -10 \text{ m/s}^2$$

19. (a)Draw the velocity-time graph of a body with uniform aceeleration .

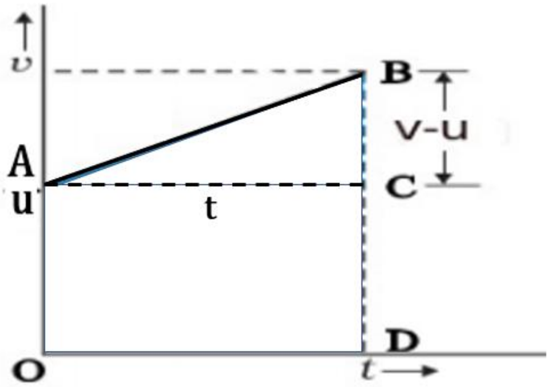
(b) Using the graph obtain

(i) Velocity - time relation

(ii) Displacement -tme relation

(iii) Displacement velocity relation

Consider a body moving with uniform acceleration . The velocity – time graph is as shown in figure



(1) Velocity – time relation

From the graph , acceleration = slope

$$a = \frac{BC}{AC}$$

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

$$v-u = at$$

$$\mathbf{v = u + at} \text{ ------------------- (1)}$$

$$\text{or } (v = v_0 + at)$$

(2) Position-time relation

Displacement = Area under the graph

s = Area of ▬ + Area of ▲

$$s = ut + \tfrac{1}{2}(v-u)\,t$$

But from equation (1)

$$v - u = at$$

$$s = ut + \tfrac{1}{2}\,at \times t$$

$$\mathbf{s = ut + \tfrac{1}{2}at^2} \text{ -----------------(2)}$$

$$\text{or } (s = v_0 t + \tfrac{1}{2}at^2)$$

(3)Position – velocity relation

Displacement = Average velocity x time

$$s = \left(\frac{v+u}{2}\right)\left(\frac{v-u}{a}\right)$$

$$s = \left(\frac{v^2-u^2}{2a}\right)$$

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

$$\mathbf{v^2 = u^2 + 2as} \text{ ---------------(3)}$$

$$\text{Or } (v^2 = v_0{}^2 + 2as)$$

20.What do you mean by stopping distance of vehicles ? Obtain its expression.

When brakes are applied to a moving vehicle, the distance it travels before stopping is called stopping distance.

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

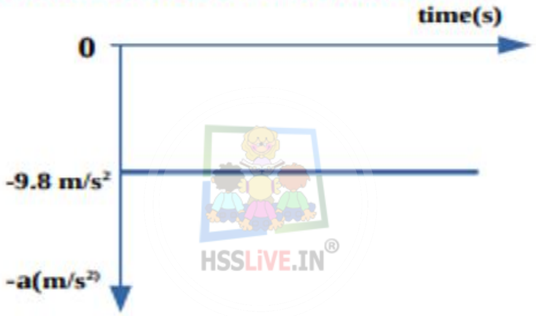
$$0 = u^2 + 2as$$

$$-u^2 = 2as$$

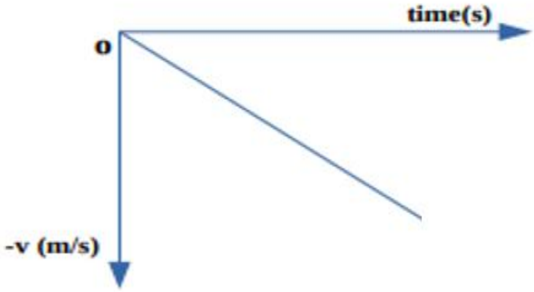
$$\mathbf{s = \frac{-u^2}{2a}}$$

21. An object is under freefall. Draw its (a) Acceleration -time graph
(b) Velocity- time graph
(c) Displacement-time graph

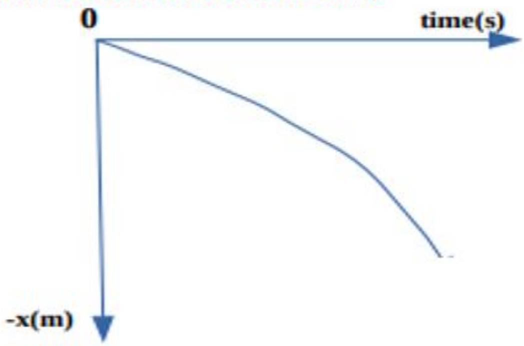
(a) Variation of acceleration with time



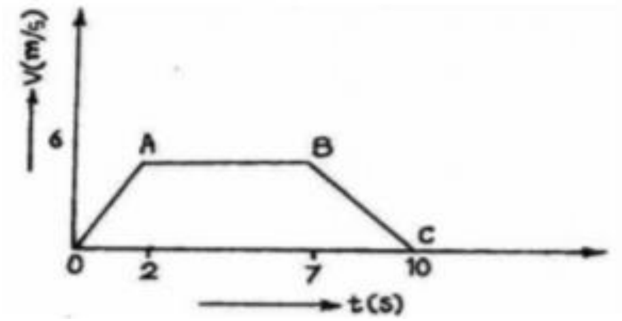
(b) Variation of velocity with time



(c) Variation of distance with time



22.Velocity – time graph of a body is given below



a) Which portion of the graph represents uniform retardation?

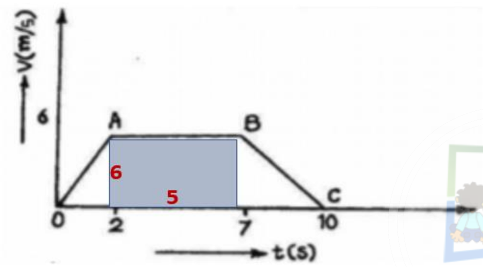
(i) OA (ii)AB (iii) BC (iv) OC

b) Find the displacement in time 2s to 7s.

c) A stone is dropped from a height h. Arrive at an expression for the time taken to reach the ground.

a)BC

b)



Displacement = area of rectangle

= 6 x 5 = 30m

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

$-h = 0 - \frac{1}{2} gt^2$

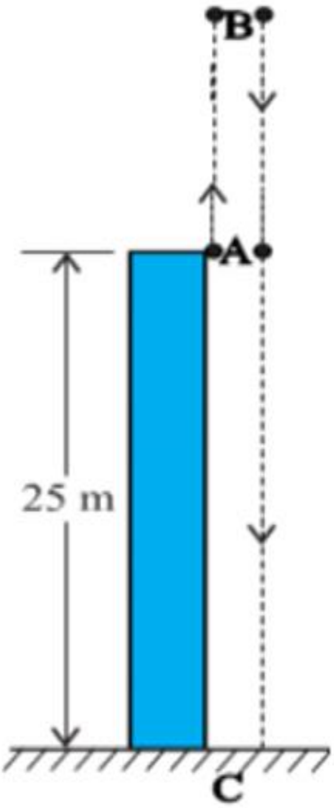
$t^2 = \frac{2h}{g}$

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

23.A ball is thrown vertically upwards with a velocity of 20 m s^{-1} from the top of a multistorey building. The height of the point from where the ball is thrown is 25.0 m from the ground.

(a) How high will the ball rise ? and

(b) how long will it be before the ball hits the ground? Take g = 10 m s^{-2}



a) $u = 20$ m/s

$v = 0$

$a = -10 m/s^2$

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

$0 - 20^2 = 2 \times -10 \times s$

$-400 = -20 s$

$s = -400/-20 = 20$ m

Total height = 20+ 25 = 45 m

(b) Total time = time fro upward motion + time for downward motion

For upward motion ,

$v = 0$

$u = 20$ m/s

$a = -10 m/s^2$

$v = u + at$

$0 = 20 + -10t$

$10 t = 20$ $t = 20/10 = 2$ s

For downward motion,

$u = 0$

$s = -45$m

$a = -10 m/s^2$

$s = ut + ½ at^2$

$-45 = 0 - ½ \times 10 \times t^2$

$-45 = -5 t^2$ $t^2 = 9$, $t = 3$ s

Total time = 2 + 3 = 5s

Chapter 3
Motion in a Plane

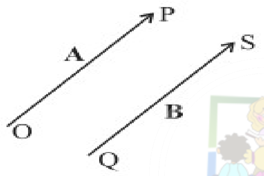
1. Differentiate scalar and vector quantities

A scalar quantity has only magnitude and no direction.
Eg. distance , speed, mass , temperature, time ,work ,power, energy, pressure, frequency, angular frequency etc.

A vector quantity has both magnitude and direction and obeys the triangle law
of addition or the parallelogram law of addition.
Eg. displacement, velocity, acceleration , momentum, force, angular velocity, torque, angular momentum etc.

2.When two vectors are said to be equal?

Two vectors A and B are said to be equal if, and only if, they have the same magnitude and the same direction.



3.What do you mean by null vectors or zero vector?

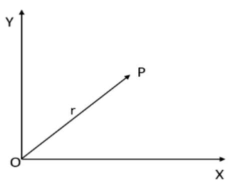
A Null vector or Zero vector is a vector having zero magnitude and is represented by O or $\bar{O}$. The result of adding two equal and opposite vectors will be a Zero vector
Eg: When a body returns to its initial position its displacement will be a zero vector.

4.What are unit vectors?

A unit vector is a vector of unit magnitude and points in a particular direction.
It has no dimension and unit. It is used to specify a direction only.

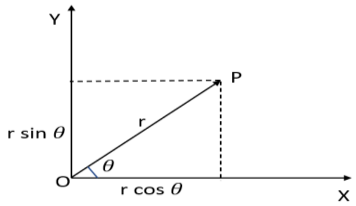
$$\hat{\mathbf{A}} = \frac{\bar{\mathbf{A}}}{|\mathbf{A}|}$$

5.The position vector of a particle P located in an x-y plane is shown in figure.



a)Redraw the figure by showing the rectangular components.
b)Write the position vector in terms of rectangular components.

a)



b) $\bar{r} = r\cos\theta\hat{\imath} + r\sin\theta\hat{\jmath}$

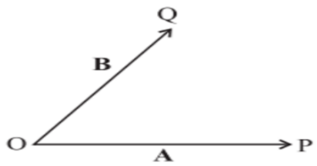
6.State triangle law of vector addition.

If two vectors are represented in magnitude and direction by the two sides of a triangle taken in order ,then their resultant is given by the third side of the triangle taken in reverse order.

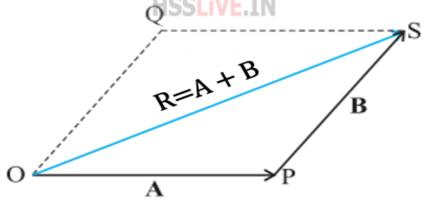
7.State parallelogram law of vector addition

If two vectors are represented in magnitude and direction by the adjacent sides of a parallelogram ,then their resultant is given by the diagonal of the parallelogram.

8.Two vectors A and B are given below.



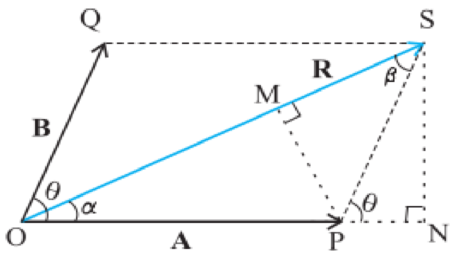
Redraw the figure and show the vector sum using parallelogram method.



9.Write the equation to find the magnitude of resultant of two vectors A and B

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

10.Derive the expression for magnitude of resultant of two vectors by analytical method. Write the expression for direction of resultant vector.



$\triangle$ SNP , $\cos\theta = PN / PS$ $\quad\quad$ $\sin\theta = SN / PS$

$\cos\theta = PN / B$ $\quad\quad$ $\sin\theta = SN / B$

$PN = B\cos\theta$ $\quad\quad$ $SN = B\sin\theta$

From the geometry of the figure,

$$OS^2 = ON^2 + SN^2$$

$$OS^2 = (OP + PN)^2 + SN^2$$

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

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

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

$$\mathbf{R = \sqrt{A^2 + B^2 + 2AB\cos\theta}}$$

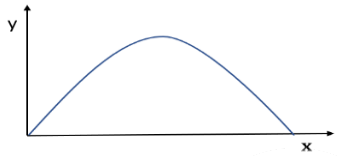
Direction , $\tan\alpha = \frac{SN}{ON}$

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

11.What is the trajectory(path) followed by a projectile?

Parabola

12. Draw the trajectory of a projectile



13.A stone is thrown up with a velocity u , which makes an angle θ with the horizontal.

a)What are the magnitudes of horizontal and vertical components of velocity?

b)How do these components vary with time?

a) Horizontal component - $u\cos\theta$ and
vertical component - $u\sin\theta$

b) Horizontal component- $u\cos\theta$ remains constant with time.

vertical component first deceases, becomes zero at the highest point of projection and then increases in reverse direction.

14.What are the values of these components at the highest point of projection?

At the highest point,Horizontal component= $u\cos\theta$
Vertical component = zero

15. A projectile has an acceleration of ……… in vertical direction and……… acceleration in horizontal direction

-9.8m s^{-2} , zero

(vertical component , $a_y = -g = -9.8 m/s^2$ and
Horizontal component $a_x = 0$)

16. Show that the path of the projectile is a parabola .

Displacement of the projectile after a time t

$$x = u\cos\theta \, t$$

$$t = \frac{x}{u\cos\theta}$$

$$y = u\sin\theta \, t - \frac{1}{2} g t^2$$

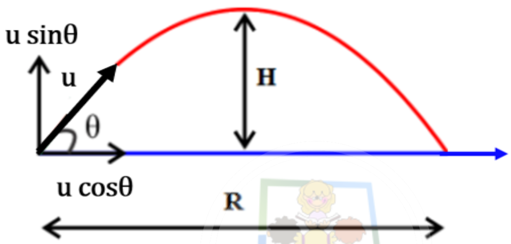
$$y = u\sin\theta \left(\frac{x}{u\cos\theta}\right) - \frac{1}{2} g \left(\frac{x}{u\cos\theta}\right)^2$$

$$y = \tan\theta \, x - \frac{g}{2u^2\cos^2\theta} x^2$$

This equation is of the form $y = a x + b x^2$ in which a and b are constants. This is the equation of a parabola,

i. e. **the path of the projectile is a parabola**.

17. Derive the equation for Time of flight, Horizontal range and Maximum height of a projectile.



Time of Flight of a projectile (T)

Consider the motion in vertical direction,

$$s = ut + ½ at^2$$

$$s=0, \quad u = u\sin\theta, \quad a = -g, \quad t = T$$

$$0 = u\sin\theta \, T - ½ gT^2$$

$$½ gT^2 = u\sin\theta \, T$$

$$\mathbf{T = \frac{2u\sin\theta}{g}}$$

Horizontal range of a projectile (R)

Horizontal range = Horizontal component of velocity x Time of flight

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

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

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

Maximum height of a projectile (H)

Consider the motion in vertical direction to the highest point

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

$u = u \sin\theta, \quad v = 0, \quad a = -g, \quad s = H$

$$0 - u^2 \sin^2\theta = -2 g H$$

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

18.What is the angle of projection for maximum horizontal range

$\mathbf{45^0}$

19. What is the maximum value of horizontal range

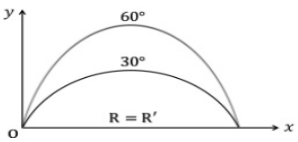
Range is maximum when $\theta = 45^0$

$$R = \frac{u^2 \sin 90}{g}$$

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

20. Find the angle of projection for which the range will be same as that in case of $\theta = 30^0$ for a given velocity of projection.

For a given velocity of projection range will be same for angles $\boldsymbol{\theta}$ and ($90-\boldsymbol{\theta}$)



Here $\theta = 30^0$

$90-\boldsymbol{\theta} = 90-30 = 60^0$

The range will be same for $30^0$and 60^0 ,for a given velocity of projection.

21.A cricket ball is thrown at a speed of 28 m s $^{-1}$ in a direction 30° above the horizontal. Calculate (a) the maximum height, (b) the time taken by the ball to return to the same level, and (c) the distance from the thrower to the point where the ball returns to the same level.

(a) $H = \dfrac{u^2 \sin^2\theta}{2g}$

$H = \dfrac{28^2 \sin^2 30}{2 \times 9.8}$

$H = 10$ m

(b) $T = \dfrac{2 u \sin\theta}{g}$

$T = \dfrac{2 \times 28 \sin 30}{9.8}$

$T = 2.9$ s

(c) $R = \frac{u^2 \sin 2\theta}{g}$

$R = \frac{28^2 \sin 60}{9.8}$

$R = 69$ m

22.What do you mean by uniform circular motion?

When an object follows a circular path at a constant speed, the motion of the object is called uniform circular motion.

Note:-

- The speed is constant in uniform circular motion.
- The velocity is not constant in uniform circular motion.
- The acceleration is not constant in uniform circular motion.

23.Give an example for a motion in which speed is constant, but velocity varying.

Uniform circular motion

24.Give an example for a motion in which speed is constant, still accelerating.

Uniform circular motion

25.What is period in uniform circular motion

The time taken by an object to make one revolution is known as its time period T. Unit-second

26.What is Frequency in uniform circular motion

The number of revolutions made in one second is called its frequency.

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

unit - hertz (Hz)

27.Define Angular velocity

Angular velocity is the time rate of change of angular displacement

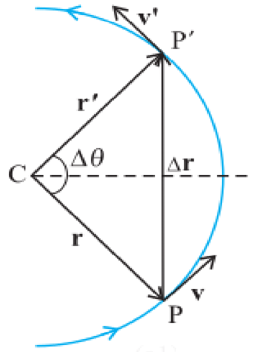
$$\omega = \frac{\Delta\theta}{\Delta t} \quad \text{or} \quad \omega = \frac{d\theta}{dt} \quad \text{or} \quad \omega = \frac{2\pi}{T} \quad \text{or} \quad \omega = 2\pi\upsilon$$

\- Unit is rad/s

28.Write the relation connecting angular velocity and linear velocity

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

29.Derive the relation connecting angular velocity and linear velocity



$$\text{angle} = \frac{\text{arc}}{\text{radius}}$$

$$\Delta\,\theta = \frac{\Delta\,r}{r}$$

$$\Delta\,r = r\;\Delta\,\theta$$

$$\frac{\Delta\,r}{\Delta t} = r\,\frac{\Delta\,\theta}{\Delta t}$$

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

30.Define angular acceleration

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

$$\alpha \;= \frac{d\,\omega}{dt}$$

$$\omega = \frac{d\,\theta}{dt}$$

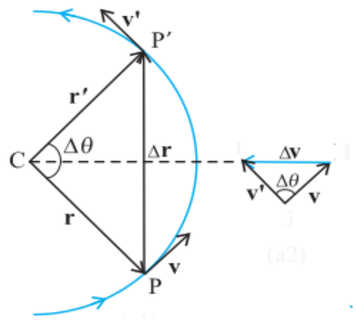
$$\alpha = \frac{d}{dt}\left(\frac{d\,\theta}{dt}\right)$$

$$\alpha = \frac{d^2\theta}{dt^2}$$

31.Define Centripetal acceleration

A body in uniform circular motion experiences an acceleration , which is directed towards the centre along its radius .This is s called centripetal acceleration .

32.Derive the expression for centripetal acceleration.



$$\frac{\Delta v}{v} = \frac{\Delta r}{r}$$

$$\Delta v = \frac{v \Delta r}{r}$$

$$\frac{\Delta v}{\Delta t} = \frac{v \Delta r}{r \Delta t}$$

$$a = \frac{v}{r} x\, r$$

$$\mathbf{a = \frac{v^2}{r}}$$

33.An insect trapped in a circular groove of radius 12 cm moves along the groove steadily and completes 7 revolutions in 100 s.
(a) What is the angular speed, and the linear speed of the motion?
(b) Is the acceleration vector a constant vector ? What is its magnitude ?

Period, $T=\frac{100}{7}$ s

(a) The angular speed ω is given by

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{\frac{100}{7}} = \frac{2\pi \, x7}{100} = 0.44 \text{ rad/s}$$

The linear speed v is :

$$v = \omega R = 0.44 \times 0.12 = 5.3 \text{ x } 10^{-2} \text{ m s}^{-1}$$

(b) The direction of velocity v is along the tangent to the circle at every point. The acceleration is directed towards the centre of the circle. Since this direction changes continuously, acceleration here is not a constant vector.

$$a = \omega^2 R = (0.44)^2 x 0.12 = 2.3x10^{-2} \text{ m s}^{-2}$$

Chapter 4
Laws of Motion

1.State Galileo's Law Inertia

If the net external force is zero, a body at rest continues to remain at rest and a body in motion continues to move with a uniform velocity.

2.What do you mean by inertia of a body?

If the net external force is zero, a body at rest continues to remain at rest and a body in motion continues to move with a uniform velocity.
This property of the body is called inertia.

3. The word inertia means .... resistance to change.

4. What are different types of inertia?

- Inertia of rest-The tendency of a body to remain in the state of rest. Eg-A person is standing in a stationary gets thrown backward when the bus starts suddenly.
- Inertia of motion - The tendency of a body to remain in the state of uniform motion.
  Eg-The a person standing in a moving bus gets thrown forward when the bus suddenly stops .
- Inertia of direction - The tendency of a body to remain in a particular direction.
  Eg- When a shopping cart makes a sudden turning, the things in it tumble down.

5.State Newton's first law of motion (Law of inertia)

Every body continues to be in its state of rest or of uniform motion in a straight line unless compelled by some external force to change that state.

6.Newton's first law of motion describes .... Inertia

7.Define momentum

Momentum, P of a body is defined to be the product of its mass m and velocity v, and is denoted by p.

$$p = m\,v$$

8.State Newton's Second Law f Motion. Write its mathematical expression.

The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts.

$$F \propto \frac{\Delta p}{\Delta t}$$

$$F = \frac{\Delta p}{\Delta t} \quad \text{or} \quad F = \frac{dp}{dt}$$

9.Why a seasoned cricketer draws his hands backwards during a catch?

By Newton's second law of motion ,

$$F=\frac{\Delta p}{\Delta t}$$

When he draws his hands backwards, the time interval (Δt) to stop the ball increases .Then force decreases and it does not hurt his hands.

10. Derive of Equation of force from Newton's second law of motion

By Newton's second law of motion ,

$$F = \frac{dp}{dt}$$

For a body of fixed mass m, p=mv

$$F = \frac{d}{dt}mv$$

$$F = m\frac{dv}{dt}$$

$$F = ma$$

11.Define newton

$$F= m\,a$$

If m=1 kg , $a=1m\,s^{-2}$

$$F=1kg \times 1\,ms^{-2}$$

$$F=1N$$

One newton is that force which causes an acceleration of $1m\,s^{-2}$ to a mass of 1 kg.

12. A bullet of mass 0.04 kg moving with a speed of 90 m/s enters a heavy wooden block and is stopped after a distance of 60 cm. What is the average resistive force exerted by the block on the bullet?

m=0.04 kg
u=90 m/s
v=0
s=60cm=0.6 m

The retardation 'a' of the bullet is assumed to be constant.

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

$$0 - 90^2 = 2 \times a \times 0.6$$

$$a = \frac{-90^2}{2 \times 0.6}$$

$$a = -6750\ m/s^2$$

The retarding force, F= ma

$$F= 0.04 \times -6750$$

$$F = -270\ N$$

The negative sign shows that the force is retarding.

13.Show that Newton's second Law is consistent with the first law. (or starting from Newton's second Law arrive at Newton's first law)

From Newton's second law,

$$F = ma$$

$$\text{If } F = 0 , \quad ma = 0$$

$$(\text{since } m \neq 0)$$

$$a = 0$$

Zero acceleration implies the state of rest or uniform linear motion . i.e, when there is no external force , the body will remain in its state of rest or of uniform motion in a straight line. This is Newtons first law of motion.

14.Define Impulse

Impulse is the the product of force and time duration, which is the change in momentum of the body.

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

$$I = F \text{ x } t$$

$$\text{Unit} = \text{kg m s}^{-1}$$

15. Define Impulsive force.

A large force acting for a short time to produce a finite change in momentum is called an impulsive force.

Eg: A cricket ball hitting a bat

16. Using Newtons second law of motion arrive at Impulse momentum Principle

Impulse is equal to the change in momentum of the body.

By Newton's second law of motion,

$$F = \frac{dp}{dt}$$

$$F \text{ x } dt = dp$$

$$I = dp$$

$$\text{Impulse} = \text{change in momentum}$$

17.A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of 12 m s^{-1}. If the mass of the ball is 0.15 kg, determine the impulse imparted to the ball.

$$\text{Impulse} = \text{change of momentum}$$

$$\text{Change in momentum} = \text{final momentum} - \text{initial momentum}$$

$$\text{Change in momentum} = 0.15 \times 12 - (0.15 \times \text{-}12)$$

$$\text{Impulse} = 3.6 \text{ N s}$$

18.Eventhough action and reaction are equal and opposite they do not cancel each other .Why?

Action and reaction forces act on different bodies, not on the same body. So they do not cancel each other , eventhough they are equal and opposite.

19.A man of mass70 kg stands on a weighing scale in a lift whichis moving,
(a) upwards with a uniform speed of 10 m s^{-1}
(b) downwards with a uniform acceleration of 5 m s^{-2}
(c) upwards with a uniform acceleration of 5 m s^{-2}
What would be the readings on the scale in each case?
(d) What would be the reading if the lift mechanism failed and it falls down freely under gravity? Take g=10 m s^{-2}

(a)When lift moves with uniform speed , a=0

$$R = mg = 70 \times 10 = 700\ N$$

$$Reading = 700/10 = 70\ kg$$

(b)Acceleration a = 5m s^{-2} downwards

$$R = m(g-a) = 70\ (10-5) = 70x5 = 350N$$

$$Reading = 350/10 = 35\ kg$$

(c) Acceleration a = 5m s^{-2} upwards

$$R = m(g+a) = 70(10+5) = 70x\ 15 = 1050N$$

$$Reading = 1050/10 = 105\ kg$$

(d) when lift falls freely a=g

$$R = m(g-g) = 0$$

$$Reading = 0$$

20.State the Law of Conservation of Momentum

The total momentum of an isolated system of interacting particles is conserved.

Or

When there is no external force acting on a system of particles ,their total momentum remains constant.

21.Prove law of conservation of momentum Using Newton's second law of motion

By Newton's second law of motion , $F=\frac{dp}{dt}$

$$When\ F = 0$$

$$\frac{dp}{dt} = 0$$

$$dp = 0\ ,$$

$$p=constant$$

Thus when there is no external force acting on a system of particles, their total momentum remains constant.

22. Prove law of conservation of momentum Using Newton's third law of motion

F_{AB} changes the momentum of body A

$$F_{AB}\,\Delta t = p'_A - p_A \text{-----------------(1)}$$

F_{BA} changes the momentum of body B

$$F_{BA}\,\Delta t = p'_B - p_B \text{ ------------(2)}$$

By Newton's third law

$$F_{AB} = -F_{BA} \qquad \text{-----------(3)}$$

$$p'_A - p_A = -(p'_B - p_B)$$

$$p'_A + p'_B = p_A + p_B$$

Total Final momentum = Total initial momentum

i.e. , the total final momentum of the isolated system equals its total initial momentum.

23.Explain the recoil of gun using law of conservation of linear momentum

By the law of conservation of momentum,as the system is isolated, the momentum remains constant

Initial momentum = Final momentum

Initial momentum of gun+ bullet system = 0

Final momentum of gun+ bullet system = 0

If p_b and p_g are the momenta of the bullet and gun after firing

$$p_b + p_g = 0$$

$$p_b = -p_g$$

The negative sign shows that gun recoils to conserve momentum.

24.Obtain the expression for Recoil velocity and muzzle velocity

Momentum of bullet after firing , $p_b = mv$

Recoil momentum of the gun after firing , $p_g = MV$

$$p_b = -p_g$$

$$mv = -MV$$

Recoil velocity of gun , $V = \frac{-mv}{M}$

Muzzle velocity of bullet , $v = \frac{-MV}{m}$

M= mass of gun, V= recoil velocity of bullet

m= mass of bullet, v=muzzle velocity of bullet

25.A shell of mass 0.020kg is fired by a gun of mass 100kg. If the muzzle speed of the shell is 80 m/s, what is the recoil speed of the gun?

$$V= \frac{mv}{M} = \frac{0.020 \; x \; 80}{100} = 0.016 m/s$$

26.Write the condition for equilibrium when two forces F_1 and F_2 act on a particle

$$\mathbf{F_1 + F_2 = 0}$$

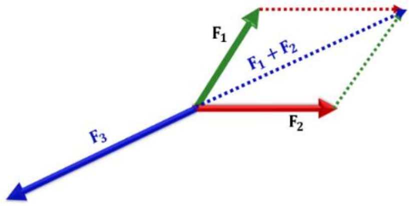
$$\mathbf{F_1 = - F_2}$$

i.e. the two forces on the particle must be equal and opposite.

27.Write the condition for equilibrium when three forces F_1, F_2 and F_3 act on a particle.

$$\mathbf{F_1 + F_2 + F_3 = 0}$$

$$\mathbf{F_1 + F_2 = - F_3}$$



28. The maximun value of limiting friction is called ....

Limiting friction or Limiting static friction.

29.State the law of static friction

The law of static friction may thus be written as , $f_s \leq \mu_s N$

where μ_s the coefficient of static friction,

30.State the Law of Kinetic Friction

$$f_k = \mu_k N$$

where μ_k the coefficient of kinetic friction,

31.Write the characteristics of static friction

- The maximum value of static friction is $(f_s)_{max}$
- The limiting value of static friction $(f_s)_{max}$, is independent of the area of contact.
- The limiting value of static friction $(f_s)_{max}$, varies with the normal force(N)

$$(f_s)_{max} \; \alpha N$$

$$\mathbf{(f_s)_{max} = \mu_s N}$$

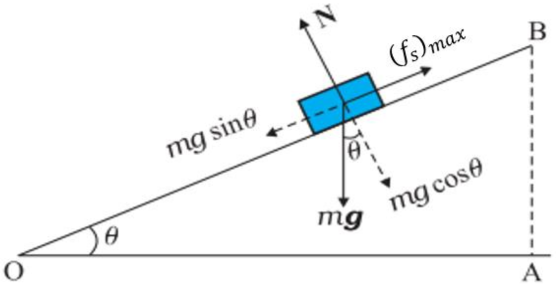
32.Write the characteristics of kinetic friction

- Kinetic friction is independent of the area of contact.
- Kinetic friction is independent of the velocity of sliding.
- Kinetic friction , f_k varies with the normal force(N)

$$f_k \; \alpha N$$

$$f_k = \mu_k N$$

33.Show that $\mu_s = \tan\theta$ (the coefficient of static friction is equal to the tangent of angle of friction) when a body just begins to slide on an inclined surface



The forces acting on a block of mass m When it just begins to slide are
(i) the weight, mg
(ii) the normal force, N
(iii) the maximum static frictional force $(f_s)_{max}$
In equilibrium, the resultant of these forces must be zero.

$$m\,g\sin\theta = (f_s)_{max}$$

But $(f_s)_{max} = \mu_s N$

$$mg\sin\theta = \mu_s N \text{------------}(1)$$

$$mg\cos\theta = N\text{------------}(2)$$

$$\text{Eqn}\frac{(1)}{(2)} \text{--------} \frac{mg\sin\theta}{m\,g\cos\theta} = \frac{\mu_s N}{N}$$

$$\mu_s = \tan\theta$$

34.Disadvantages of friction

In a machine with different moving parts, friction opposes relative motion and thereby dissipates power in the form of heat, etc. Friction produces wear and tear.

35.Advantages of friction(Friction is a necessary evil)

Kinetic friction is made use of by brakes in machines and automobiles.
We are able to walk because of static friction.
The friction between the tyres and the road provides the necessary external force to accelerate the car.

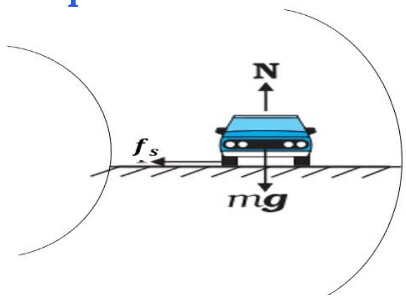
36.Methods to reduce friction

(1)Lubricants are a way of reducing kinetic friction in a machine.
(2)Another way is to use ball bearings between two moving parts of a machine.
(3) A thin cushion of air maintained between solid surfaces in relative motion is another effective way of reducing friction.

37.A car moving on a curved level road. What are the various forces acting on the car?

(i) The weight of the car, mg
(ii) Normal reaction, N
(iii) Frictional force, f_s

38.Derive the expression for maximum safe speed on a curved level road



$$N = mg$$

The static friction provides the centripetal acceleration

$$f_s = \frac{mv^2}{R}$$

$$\text{But}, f_s \leq \mu_s N$$

$$\frac{mv^2}{R} \leq \mu_s mg \quad (N=mg)$$

$$v^2 \leq \mu_s Rg$$

$$\mathbf{v_{max}} = \sqrt{\mu_s Rg}$$

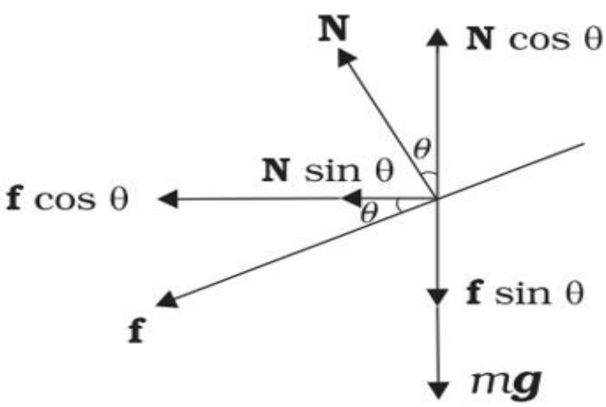
39. a) What do you mean by banking of curved roads?

b) Obtain the expression for maximum permissible speed of a vehicle on a banked road.

c)Write the expression for optimum speed (without considering frictional force)

a)Raising the outer edge of a curved road above the inner edge is called banking of curved roads.

b)



$$N\cos\theta = mg + f\sin\theta$$
$$N\cos\theta - f\sin\theta = mg \text{ -------------(1)}$$

The centripetal force is provided by the horizontal components of N andf_s.

$$N\sin\theta + f\cos\theta = \frac{mv^2}{R} \text{ -------------(2)}$$

$$\frac{Eqn(1)}{Eqn(2)} \text{ ----- } \frac{N\cos\theta - f\sin\theta}{N\sin\theta + f\cos\theta} = \frac{mg}{\frac{mv^2}{R}}$$

Dividing throughout by $N\cos\theta$

$$\frac{1 - \frac{f}{N}\tan\theta}{\tan\theta + \frac{f}{N}} = \frac{Rg}{v^2}$$

$$\frac{1 - \mu_s\tan\theta}{\tan\theta + \mu_s} = \frac{Rg}{v^2}$$

$$v^2 = \frac{Rg(\mu_s + \tan\theta)}{1 - \mu_s\tan\theta}$$

$$v_{max} = \sqrt{\frac{Rg(\mu_s + \tan\theta)}{1 - \mu_s\tan\theta}}$$

c)If friction is absent, $\mu_s = 0$

Then Optimum speed, $v_{optimum} = \sqrt{Rg\tan\theta}$

40.A circular racetrack of ra dius 300 m is banked at an angle of 15°. If the coefficient of friction between the wheels of a race-car and the road is 0.2, what is the

(a) optimum speed of the race car to avoid wear and tear on its tyres, and

(b) maximum permissible speed to avoid slipping ?

(a)

r = 300 m ; θ = 15° ; μ_s = 0.2

So the optimum speed becomes,

$$v_o = \sqrt{rg\tan\theta}$$

$$\therefore v_o = \sqrt{300\times9.8\times\tan 15}$$

$$\therefore v_o = \sqrt{300\times9.8\times0.2679} = 28.1\,m/s$$

(b)

Maximum permissible speed on banked road is,

$$v_{max} = \sqrt{\frac{rg(\tan\theta + \mu_s)}{1 - \mu_s\tan\theta}}$$

$$\therefore v_{max} = \sqrt{\frac{300\times9.8\times(\tan 15 + 0.2)}{(1 - 0.2\times\tan 15)}}$$

$$v_{max} = \sqrt{\frac{300\times9.8\times(\tan 15 + 0.2)}{(1 - 0.2\times\tan 15)}}$$

$$v_{max} = \sqrt{\frac{300\times9.8\times(0.2679 + 0.2)}{(1 - 0.2\times0.2679)}} = 38.1\,m/s$$

Chapter 5
Work ,Energy and Power

1.Define scalar product or Dot Product two vectors $\vec{A}$ and $\vec{B}$.

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

2.Some properties of dot product.

$$\hat{\imath} \cdot \hat{\imath} = \hat{\jmath} \cdot \hat{\jmath} = \hat{k} \cdot \hat{k} = 1$$
$$\hat{\imath} \cdot \hat{\jmath} = \hat{\jmath} \cdot \hat{k} = \hat{k} \cdot \hat{\imath} = 0$$
$$\vec{A} \cdot \vec{A} = A^2$$

3.If two vectors $\vec{A}$ and $\vec{B}$ are perpendicular, then their dot product will be.............

zero $\quad (\vec{A} \cdot \vec{B} = A\,B\cos 90 = 0)$

4.Define work.

The work done by the force is defined to be the product of component of the force in the direction of the displacement and the magnitude of this displacement.

$$W = \vec{F} \cdot \vec{d}$$

5.Write the situations in which work done by a body is zero

(i) when the displacement is zero .
(ii)when the force is zero.
(iii) the force and displacement are mutually perpendicular
W=Fd cos 90 = 0.

6.Give an example for zero Work.

When you push hard against a rigid brick wall, the force you exert on the wall does no work.
A weightlifter holding a 150 kg mass steadily on his shoulder for 30 s does no work on the load during this time.

7.Give an example for Positive Work

Workdone by Gravitational force on a freely falling body is positive

8.Give an example of Negative work

The the work done by friction is negative ($\cos 180^{\circ} = -1$).

9.Find out the sign of the workdone in following cases.

a)Workdone by a man in lifting a bucket out of a well.

Positive

b)Workdone by friction on a body sliding down an inclined plane

Negative

c)Workdone by an applied force on a body moving on a rough horizontal surface

Positive

d)Workdone by the resistive force on air on a vibrating pendulum

Negative

e)Workdone gravitational force during the motion of an object on a horizontal surface.

Zero

10. What is the work done by centripetal force on a body moving in circular path

Zero. Here $\theta = 90^{\circ}$, $W = Fd\cos 90 = 0$.

11. 1 horse power,1HP= -----------Watt.

746W

2. 1 kilowatt-hour, 1kWh = ------------------ J

3.6×10^6 J

13. Kilowatt-hour is the unit of ------------

Energy

14.Find the workdone by a force $\vec{F} = (3\hat{i} + 4\hat{j} - 5\hat{k})$ N , if the displacement Produced is
$\vec{d} = (5\hat{i} + 4\hat{j} + 3\hat{k})$ m.

$$W = \vec{F}.\vec{d}$$

$$W = F_x d_x + F_y d_y + F_z d_z$$

$$= (3 \times 5) + (4 \times 4) + (-5 \times 3)$$

$$W = 16\ J$$

15. The energy possessed by a body by virtue of its motion is called---------

Kinetic energy

16. The energy stored by virtue of the position or configuration of a body(state of strain) is called-------------

Potential Energy.

17. Calculate the work done in lifting a body of mass 10kg to a height of 10m above the ground

W= F x d = mg x h =10 x 9.8 x10 =980J

18. Two bodies of masses m_1 and m_2 have same momenta. What is the ratio of their kinetic energies?

$$\text{KE},\quad K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

$$K_1 = \frac{p^2}{2\,m_1} \qquad K_2 = \frac{p^2}{2\,m_2}$$

$$K_1 / K_2 = m_2/m_1$$

$$K_1 : K_2 = m_2 : m_1$$

19. A light body and heavy body have same momenta, Which one has greater kinetic energy?

$$\text{KE},\ K = \frac{p^2}{2m}$$

$$K \propto \frac{1}{m}$$

Lighter body will have more Kinetic energy.

19. A light body and heavy body have same KE, Which one has greater momentum?

$$p = \sqrt{2mK}$$

$$p \propto \sqrt{m}$$

Heavier body will have more momentum.

20.Power is the scalar product of force and -------------

Velocity ($P = F.v$)

21.Write the characteristics of conservative forces.

- A conservative force can be derived from a scalar quantity.

$$F = \frac{-dV}{dx} \text{ where V is a scalar}$$

- The work done by a conservative force depends only upon initial and final positions of the body
- The work done by a conservative force in a cyclic process is zero

22.Give two examples for conservative forces

Eg: Gravitational force, Spring force.

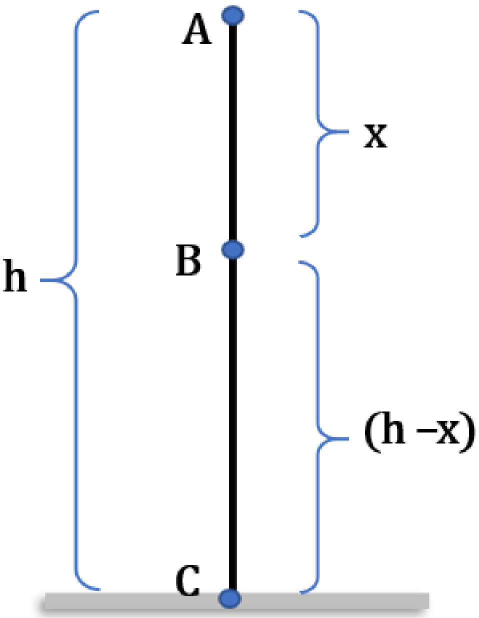
23.Give two examples for non conservative forces.

Frictional force , air resistance are non conservative forces.

24. State and prove the law of conservation of mechanical energy for a freely falling body.

The total mechanical energy of a system is conserved if the forces, doing work on it, are conservative.

Consider a body of mass m falling freely from a height h



At Point A

PE = mgh

KE = 0 (since v=0)

TE= mgh + 0

TE= mgh-----------(1)

At Point B

PE = mg (h-x)

KE = ½ mv^2

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

u=0, a=g , s= x

$v^2 = 2gx$

KE = ½ m x 2gx =mgx

TE = mg (h-x) + mgx

TE = mgh--------------(2)

At Point C

PE = 0 (Since h=0

KE = ½ mv^2

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

u=0, a=g , s= h

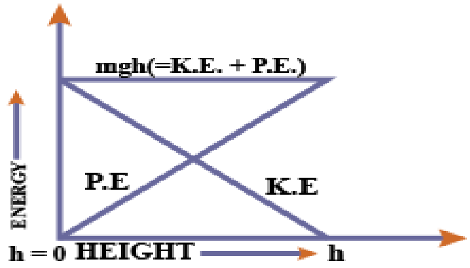
$v^2 = 2gh$

KE = ½ m x 2gh=mgh

TE = 0 + mgh

TE = mgh--------------(3)

From eqns (1), (2) and (3), it is clear that the total mechanical energy is conserved during the free fall.



25.Show that the gravitational potential energy of the object at height h, is completely converted to kinetic energy on reaching the ground.

PE at a height h, V = mgh

When the object is released from a height it gains KE

K = ½ mv^2

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

u=0, a=g , s=h

$v^2 = 2gh$

K = ½ m x 2gh

K= mgh

26.The energy possessed by a body by virtue of its motion is called .... Kinetic energy

27.The eneegy possessed by a body by virtue of the position or configuration of a body is called .... Potential energy.

28.A body at a height h above the surface of earth possesses .... due to its position. Potential energy.

29.A Stretched or compressed spring possesses .... due to its state of strain. potential energy

30.State and prove work-energy theorem

The work-energy theorem can be stated as :The change in kinetic energy of a particle is equal to the work done on it by the net force.

Proof

For uniformly accelerated motion

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

Multiplying both sides by $\frac{1}{2}m$, we have

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas = Fs$$

$$K_f - K_i = W$$

Change in KE = Work

31.In a ballistics demonstration a police officer fires a bullet of mass 50.0 g with speed 200 m s^{-1} on soft plywood of thickness 2.00 cm. The bullet emerges with only 10% of its initial kinetic energy. What is the emergent speed of the bullet ?

Answer The initial kinetic energy of the bullet is $mv^2/2$ = 1000 J. It has a final kinetic energy of $0.1 \times 1000 = 100$ J. If v_f is the emergent speed of the bullet,

$$\frac{1}{2}mv_f^2 = 100 \text{ J}$$

$$v_f = \sqrt{\frac{2 \times 100 \text{ J}}{0.05 \text{ kg}}}$$

$$= 63.2 \text{ m s}^{-1}$$

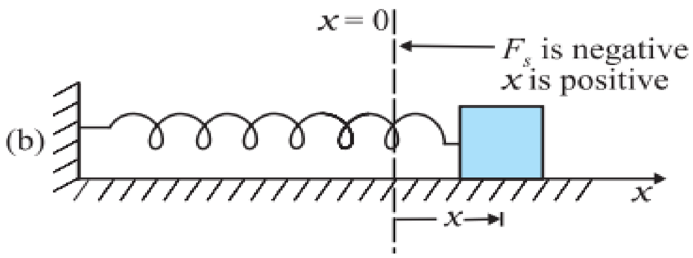
32.State Hooke's law for a spring

Hooke's law states that ,for an ideal spring, the spring force F is proportional displacement x of the block from the equilibrium position.

$$F = -kx$$

The constant k is called the spring constant. Its unit is Nm^{-1}

33.Derive the expression for potential energy of a spring



Then the spring force $F = -kx$

The work done by the spring force is

$$W = \int_0^x F\,dx$$

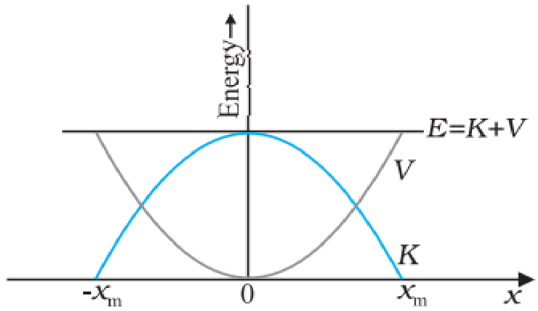
$$W = -\int_0^x kx\,dx$$

$$W = -\frac{1}{2}kx^2$$

This work is stored as potential energy of spring

$$PE = \frac{1}{2}kx^2$$

34.Draw the graphical variation of kinetic Energy and potential of a spring



35.Write Einstein's mass energy relation.

$$\mathbf{E = m\,c^2}$$

36.Find the amount of energy is associated with 1 kilogram of matter

$$E = m\,c^2$$

$$E = 1\times(3\times10^8)^2\ J$$

$$E = 9\times10^{16}\ J.$$

37.Write the expression for instantaneous power in dot product form

$$P = \frac{dW}{dt}$$

The work done, dW = F. dr.

$$P = F.\frac{dr}{dt}$$

$$P = F . v$$

Instantaneous power is the dot product of force and velocity.

38.An elevator can carry a maximum load of 1800 kg (elevator + passengers) is moving up with a constant speed of 2 m s–1. The frictional force opposing the motion is 4000 N. Determine the minimum power delivered by the motor to the elevator in watts as well as in horse power.

The downward force on the elevator is F = m g + Frictional Force

$= (1800 \times 10) + 4000$

$= 22000$ N

Power, P = F. v

$= 22000 \times 2$

$= 44000$ W

In horse power, power = 44000/746

=59 hp

39.Differentiate Elastic and inelastic collisions.Give examples for each.

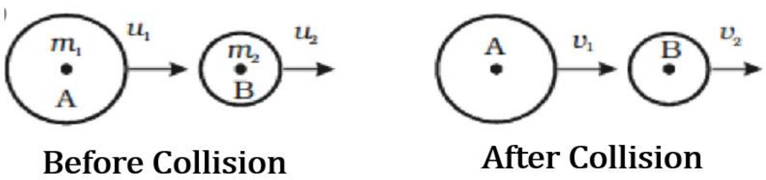
The collisions in which both linear momentum and kinetic energy are conserved are called elastic collisions.

Eg: Collision between sub atomic particles

The collisions in which linear momentum is conserved, but kinetic energy is not conserved are called inelastic collisions. . Part of the initial kinetic energy is transformed into other forms of energy such as heat,sound etc..

Eg: Collision between macroscopic objects

40.For elastic collisions in one dimension show that the relative velocity before collision is numerically equal to relative velocity after collision.



By the conservation of momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \text{ --------------(1)}$$
$$m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$$
$$m_1(u_1 - v_1) = m_2(v_2 - u_2) \text{---------------(2)}$$

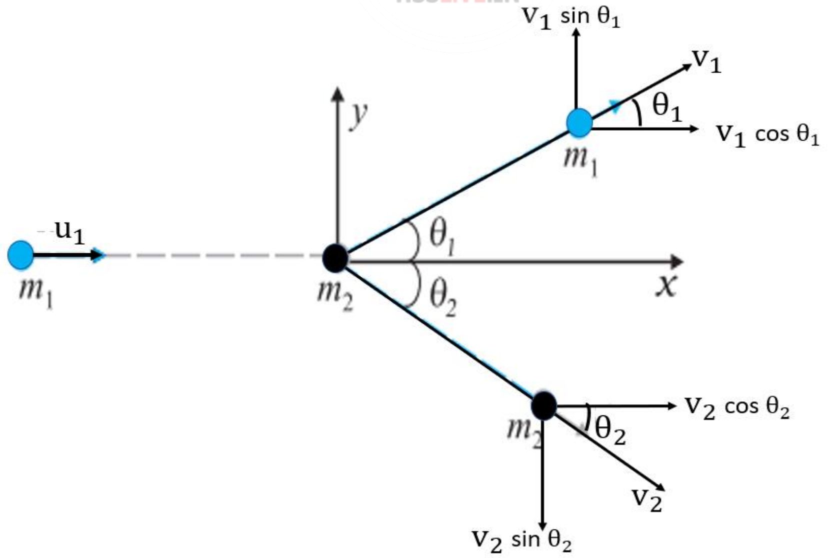
By the conservation of kinetic energy

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \text{-----------(3)}$$
$$\frac{1}{2}m_1u_1^2 - \frac{1}{2}m_1v_1^2 = \frac{1}{2}m_2v_2^2 - \frac{1}{2}m_2u_2^2$$
$$\frac{1}{2}m_1\,(u_1^2 - v_1^2) = \frac{1}{2}m_2(v_2^2 - u_2^2)$$
$$m_1\,(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2) \quad \text{-------------(4)}$$

$$\text{Eqn } \frac{(4)}{(2)} \quad \text{------------} \quad \frac{m_1\,(u_1^2-v_1^2)}{m_1(u_1-v_1)} = \frac{m_2(v_2^2-u_2^2)}{m_2(v_2-u_2)}$$
$$\frac{(u_1+v_1)\,(u_1-v_1)}{(u_1-v_1)} = \frac{(v_2+u_2)(v_2-u_2)}{(v_2-u_2)}$$
$$u_1 + v_1 = v_2 + u_2 \quad \text{-------------(5)}$$
$$u_1 - u_2 = -(v_1 - v_2) \text{--------(6)}$$

i.e., relative velocity before collision is numerically equal to relative velocity after collision.

41.For elastic collisions of a moving mass m_1 with the stationary mass m_2 write the expression for momentum conservation and kinetic energy conservation



Equation for conservation of momentum in x direction

$$m_1u_1 = m_1v_1\cos\theta_1 + m_2v_2\cos\theta_2$$

Equation for conservation of momentum in y direction

$$0 = m_1v_1\sin\theta_1 - m_2v_2\sin\theta_2$$

Equation for conservation of kinetic energy,(KE is a scalar quantity)

$$\frac{1}{2}m_1u_1^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

Chapter 6
Systems of Particles and Rotational Motion

1.Define centre of mass

The centre of is a hypothetical point where the entire mass of an object may be assumed to be concentrated to visualise its motion.

2.Write the expression for position vector of centre of mass of an n particle system

$$\vec{R} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots \ldots\ldots + m_n\vec{r}_n}{M}$$

where $M = m_1 + m_2 + \ldots\ldots + m_n$

3.Write the expression for velocity of centre of mass of an n particle system

$$\vec{V} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2 + \cdots \ldots\ldots + m_n\vec{v}_n}{M} \quad \text{--------------(2)}$$

where $M = m_1 + m_2 + \ldots\ldots + m_n$

4.Write the expression for acceleration of centre of mass of an n particle system

$$\vec{A} = \frac{m_1\vec{a}_1 + m_2\vec{a}_2 + \cdots \ldots\ldots + m_n\vec{a}_n}{M} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where $M = m_1 + m_2 + \ldots\ldots + m_n$

5.When the total external force on the system is zero the velocity of the centre of mass remains constant or the CM of the system is in........................

uniform motion.

6.Define vector product or cross product of two vectors $\vec{A}$ and $\vec{B}$

Vector product of two vectors $\vec{A}$ and $\vec{B}$ is defined as

$$\vec{A} \times \vec{B} = AB \sin\theta \, \hat{n}$$

where A and B are magnitudes of $\vec{A}$ and $\vec{B}$

θ is the angle between $\vec{A}$ and $\vec{B}$

$\hat{n}$ is the unit vector perpendicular to the plane containing $\vec{A}$ and $\vec{B}$

7.Some properties of vector product

- $\vec{A} \times \vec{A} = \vec{0}$
- $\hat{\imath} \times \hat{\imath} = 0$, $\hat{\jmath} \times \hat{\jmath} = 0$, $\hat{k} \times \hat{k} = 0$
- $\hat{\imath} \times \hat{\jmath} = \hat{k}$, $\hat{\jmath} \times \hat{k} = \hat{\imath}$, $\hat{k} \times \hat{\imath} = \hat{\jmath}$
- $\hat{\jmath} \times \hat{\imath} = -\hat{k}$, $\hat{k} \times \hat{\jmath} = -\hat{\imath}$, $\hat{\imath} \times \hat{k} = -\hat{\jmath}$

8.. Write the relation connecting angular velocity and its linear velocity.

$$\vec{v} = \vec{\omega} \times \vec{r}$$

9. Define Angular acceleration

Angular acceleration $\vec{\alpha}$ is defined as the time rate of change of angular velocity.

$$\vec{\alpha} = \frac{d\vec{\omega}}{dt} \qquad \text{unit rad}/s^2 \quad \text{or} \quad \text{rad } s^{-2}$$

10.The rotational analogue of force is ----------------

Torque or Moment of force

11.Write the equation for torque or moment of force

$$\vec{\tau} = \vec{r} \times \vec{F}$$

12.The handle of the door is always fixed at the edge of the door which is located at a maximum possible distance away from hinges. Give reason.

$$\vec{\tau} = \vec{r} \times \vec{F} = rF \sin\theta$$

When r is maximum ,torque will be maximum.

The handle is fixed at the edge to increase r and hence to make torque maximum.

13.Find the torque of a force $7\hat{i} + 3\hat{j} - 5\hat{k}$ about the origin. The force acts on a particle whose position vector is $\hat{i} - \hat{j} + \hat{k}$.

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\vec{\tau} = (\hat{i} - \hat{j} + \hat{k}) \times (7\hat{i} + 3\hat{j} - 5\hat{k})$$

$$\vec{\tau} = \begin{array}{c} \begin{matrix} + & - & + \end{matrix} \\ \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -1 & 1 \\ 7 & 3 & -5 \end{vmatrix} \end{array}$$

$$\vec{\tau} = \hat{i}\,[(-1 \times -5) - (3 \times 1)] - \hat{j}\,[(1\text{x-}5) - (7\text{x}1)] + \hat{k}\,[(1\text{x}3) - (7\text{x-}1)]$$

$$\vec{\tau} = \hat{i}\,[5 - 3] - \hat{j}\,[-5 - 7] + \hat{k}\,[3 - -7]$$

$$\vec{\tau} = 2\hat{i} + 12\hat{j} + 10\hat{k}$$

14.Angular momentum is the rotational analogue of ---------------

linear momentum.

15. Write the relation connecting angular momentum and linear momentum.

$$\vec{l} = \vec{r} \times \vec{p}$$

16.The moment of linear momentum is called ---------------

Angular momentum

17.Write the relation connecting torque and angular momentum

$$\vec{\tau} = \frac{d\vec{l}}{dt}$$

18. Deduce the relation connecting torque and angular momentum (or) Show that the time rate of change of the angular momentum of a particle is equal to the torque acting on it.

$$\vec{l} = \vec{r} \times \vec{p}$$

Differentiating
$$\frac{d\vec{l}}{dt} = \frac{d}{dt}(\vec{r} \times \vec{p})$$

$$\frac{d\vec{l}}{dt} = \frac{d\vec{r}}{dt} \times \vec{p} + \vec{r} \times \frac{d\vec{p}}{dt}$$

$$\vec{p} = m\vec{v} \ , \frac{d\vec{r}}{dt} = \vec{v} \, , \frac{d\vec{p}}{dt} = \vec{F}$$

$$\frac{d\vec{l}}{dt} = \vec{v} \times m\vec{v} + \vec{r} \times \vec{F}$$

$$\vec{v} \times \vec{v} = 0 \, , \ (\vec{r} \times \vec{F} = \vec{\tau})$$

$$\frac{d\vec{l}}{dt} = 0 + \vec{\tau}$$

$$\boldsymbol{\vec{\tau} = \frac{d\vec{l}}{dt}}$$

19.The time rate of change of the angular momentum of a particle is equal to the --------------- acting on it.

Torque

20.State and prove the law of conservation of angular momentum

If the total external torque on a system of particles is zero, then the total angular momentum of the system is conserved i.e, remains constant.

$$\vec{\tau}_{ext} = \frac{d\vec{L}}{dt}$$

If external torque, $\vec{\tau}_{ext} = 0$,

$$\frac{d\vec{L}}{dt} = 0$$

$$\vec{L} = \text{constant}$$

21.Write an example of a motion in which angular momentum remains constant

Motion of planets around sun.

22.What do you mean by equilibrium of a rigid body?

A rigid body is said to be in mechanical equilibrium, if it is in both translational equilibrium and rotational equilibrium.

23.What is translational equilibrium?

When the total external force on the rigid body is zero, then the total linear momentum of the body does not change with time and the body will be in translational equilibrium .

24.What is rotational equilibrium?

When the total external torque on the rigid body is zero, the total angular momentum of the body does not change with time and the body will be in rotational equilibrium .

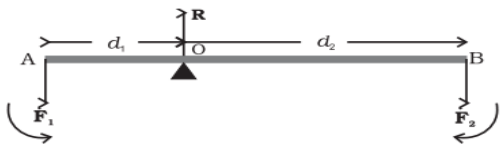
25.What is partial equilibrium?

A body may be in partial equilibrium, i.e., it may be in translational equilibrium and not in rotational equilibrium, or it may be in rotational equilibrium and not in translational equilibrium.

26.Define a couple.

A pair of equal and opposite forces with different lines of action is known as a couple. A couple produces rotation without translation.

27.State the principle of moments.



The lever is a system in mechanical equilibrium.

For rotational equilibrium the sum of moments must be zero,

$$d_1F_1 - d_2F_2 = 0$$

$$\mathbf{d_1F_1 = d_2F_2}$$

28.What is centre of gravity of a body?

The Centre of gravity of a body is the point where the total gravitational torque on the body is zero.

29. Moment of Inertia is the rotational analogue of ------------

Mass.

30.The rotational analogue of mass is called--------------------

Moment of Inertia

31. Mass is a measure of ----------------- and moment of inertia is a measure of ------------------------

Inertia , Rotational inertia

32. Writ the expression for moment of inertia of a particle of mass m rotating about an axis

$I = mr^2$

33. Write the equation for rotational kinetic energy.

$$\text{Rotational kE} = \frac{1}{2}I\omega^2$$

34. What do you mean by radius of gyration ?

The radius of gyration can be defined as the distance of a mass point from the axis of roatation whose mass is equal to the whole mass of the body and whose moment of inertia is equal to moment of inertia of the whole body about the axis.

$$I = Mk^2$$

$$k = \sqrt{\frac{I}{M}}$$

35.The moment of inertia of a disc of mass 'M' and radius R about an axis passing through its centre and perpendicular to its plane is $\frac{MR^2}{2}$. What is the radius of gyration of this case.

$$k = \sqrt{\frac{I}{M}}$$

$$k = \sqrt{\frac{\frac{MR^2}{2}}{M}} = \sqrt{\frac{R^2}{2}} = \frac{R}{\sqrt{2}}$$

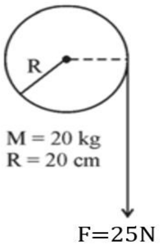
36.What is a flywheel?

A disc with a large moment of inertia is called a flywheel. It is used in machines, that produce rotational motion.

37.Write the rotational analogue of the following equations in translational motion

	Linear Motion	Rotational Motion about a Fixed Axis
1	Displacement x	Angular displacement θ
2	Velocity $v = dx/dt$	Angular velocity $\omega = d\theta/dt$
3	Acceleration $a = dv/dt$	Angular acceleration $\alpha = d\omega/dt$
4	Mass M	Moment of inertia I
5	Force $F = Ma$	Torque $\tau = I\alpha$
6	Work $dW = F\,ds$	Work $W = \tau\, d\theta$
7	Kinetic energy $K = Mv^2/2$	Kinetic energy $K = I\omega^2/2$
8	Power $P = F v$	Power $P = \tau\omega$
9	Linear momentum $p = Mv$	Angular momentum $L = I\omega$

38.A cord of negligible mass is wound round the rim of a flywheel mounted on a horizontal axle as shown in figure.



Calculate the angular acceleration of the wheel if steady pull of 25N is applied on the cord. Moment of inertia of flywheel about its axis=$\frac{MR^2}{2}$

$$I=\frac{MR^2}{2} = \frac{20 \times 0.2^2}{2} = 0.4\ kgm^2$$

Torque , τ = force xperpendicular distance

$$\tau = 25 \times 0.2 = 5Nm$$

$$\tau = I \propto$$

$$\propto = \frac{\tau}{I} = \frac{5}{0.4} = 12.5 rad/s^2$$

39.A girl rotates on a swivel chairas shown below.

a)what happens to her angular speed when she stretches her arms

b) what happens to her angular speed when she folds her arms

c)Name and state the conservation law applied for your justification

a)When she stretches her arms, the moment of inertia increases and hence the angular speed decreases.

b)When she folds her arms, the moment of inertia decreases and hence the angular speed increases.

c) Law of conservation of angular momentum.

If the total external torque on a system of particles is zero, then the total angular momentum of the system is conserved i.e, remains constant.

(If $\vec{\tau}_{ext} = 0$, $\vec{L} = I\vec{\omega}$ = constant .When I increases $\vec{\omega}$ decreases and vice versa)

Chapter 7
Gravitation

1.State Kepler's first law of planetary motion(Law of orbits)

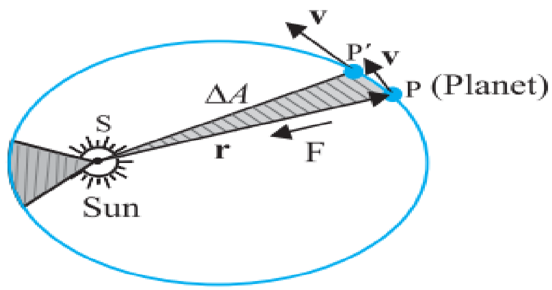
All planets move in elliptical orbits with the Sun situated at one of the foci of the ellipse.

2.State Kepler's second law of planetary motion(Law of areas)

The line that joins any planet to the sun sweeps equal areas in equal intervals of time. i.e, areal velocity $\frac{\Delta\vec{A}}{\Delta t}$ is constant

3.Kepler's second law (law of areas) is a consequence of conservation of ……………………… angular momentum.

4.Prove Kepler's second law of planetary mtion.



The area swept out by the planet of mass m in time interval Δt is

$$\Delta\vec{A} = \frac{1}{2}(\vec{r}\times\vec{v}\Delta t)$$

$$\vec{p} = m\vec{v},$$

$$\vec{v} = \frac{\vec{p}}{m}$$

$$\frac{\Delta\vec{A}}{\Delta t} = \frac{1}{2}\left(\vec{r}\times\frac{\vec{p}}{m}\right)$$

$$\vec{L} = \vec{r}\times\vec{p}$$

$$\frac{\Delta\vec{A}}{\Delta t} = \frac{\vec{L}}{2m}$$

Here angular momentum, $\vec{L}$ is a constant.

$$\frac{\Delta\vec{A}}{\Delta t} = \text{constant}$$

This is the law of areas.

5.State Kepler's third law of planetary motion(Law of periods)

The square of the time period of revolution of a planet is proportional to the cube of the semi- major axis of the ellipse traced out by the planet.

$$T^2 \propto a^3$$

6.Prove Kepler's third law of planetary mtion.

Period of a satellite, $T = 2\pi\sqrt{\frac{(R+h)^3}{GM}}$

$$T^2 = 4\pi^2\frac{(R+h)^3}{GM}$$

$$T^2 = \frac{4\pi^2}{GM}(R+h)^3$$

$$T^2 \propto (R+h)^3$$

$$T^2 \propto a^3$$

Which is Kepler's Law of Periods.

7.State Universal Law of Gravitation

Every body in the 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 .

$$\mathbf{F = G\frac{m_1 m_2}{r^2}}$$

8. The value of Gravitational Constant.

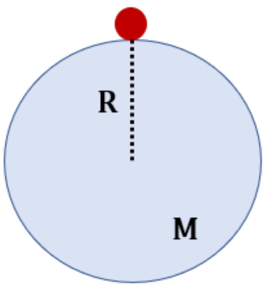
$$G = 6.67\times10^{-11}\ \mathrm{N\ m^2/kg^2}$$

9.Define acceleration due to gravity of the Earth

The acceleration gained by a body due to the gravitational force of earth is called acceleration due to gravity.

10. Obtain the expression for acceleration due to gravity on the surface of the earth (or) Obtain the relation connecting g and G.

Consider a body of mass m on the surface of earth of mass M and radius R. The gravitational force between body and earth is given by



$$F = \frac{GMm}{R^2} \text{ -----------(1)}$$

By Newton's second law

$$F=mg$$

where g is acceleration due to gravity

From Eq (1) and (2)

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

$$\mathbf{g=\frac{GM}{R^2}}$$

11.The average value of g on the surface of earth is -------. $9.8\mathrm{ms^{-2}}$.

12. Acceleration due to gravity is independent of------------(mass of the body/mass of earth).

mass of the body

13.A man can lift a mass of 15kg on earth.What will be the maximum mass that can be lifted by him by applying the same force on moon.

6x15 =90kg

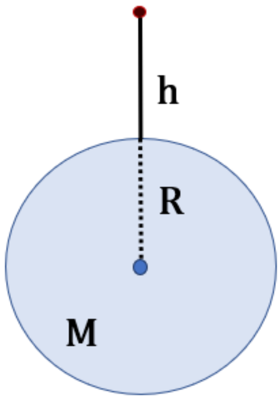
(Acceleration due to gravity on the surface of moon is $\frac{1}{6}$ times that on earth. So he can lift 6 times massive objects on the surface of moon)

14.A mass of 30kg is taken from earth to moon. What will be its mass and weight on the surface of moon

Mass on the moon=30kg (mass remains the same)

$$\text{Weight on the moon} = \frac{30\ x 9.8}{6} = 49\text{N}$$

15.Obtain the expression for Acceleration due to gravity at a height h above the surface of the earth.



On the surface of earth

$$g = \frac{GM}{R^2} \text{ ------------(1)}$$

At a height above the surface of earth

$$g_h = \frac{GM}{(R+h)^2} \text{ ----------(2)}$$

For , h << R

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

$$g_h = \frac{GM}{R^2}(1+\frac{h}{R})^{-2}$$

Substituting from eq(1)

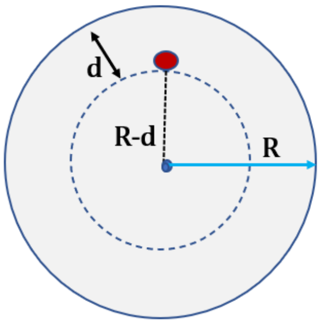
$$g_h = g(1+\frac{h}{R})^{-2}$$

Using binomial expression and neglecting higher order terms.

$$g_h \cong g\,(1-\frac{2h}{R})$$

16.Derive the expression for acceleration due to gravity at a depth d below the surface of the earth

We assume that the entire earth is of uniform density. Then mass of earth



Acceleration due to gravity on the surface of earth

$$g=\frac{GM}{R^2} \text{ -------------(1)}$$

But $M=\frac{4}{3}\pi R^3\rho$

$$g=\frac{G}{R^2}(\frac{4}{3}\pi R^3\rho)$$

$$g = \frac{4}{3}\pi R\rho G \text{ ---------------(2)}$$

Acceleration due to gravity at a depth d below the surface of earth

$$g_d = \frac{4}{3}\pi(R-d)\rho G \text{ ---------(3)}$$

$\frac{eq(3)}{eq(2)}$ ------ $\frac{g_d}{g} = \frac{\frac{4}{3}\pi(R-d)\rho G}{\frac{4}{3}\pi R\rho G}$

$$\frac{g_d}{g} = \frac{(R-d)}{R}$$

$$g_d = g(1-\frac{d}{R})$$

17.The acceleration due gravity --------------(decreases/increases) , as we go above earth's surface and ---------------(decreases/increases) ,as we go down below earth's surface.

Decreases ,Decreases.

18.The acceleration due gravity is -------------------at the centre of earth.

Zero

19.At what height the value of acceleration due to gravity will be half of that on surface of earth. (Given the radius of earth R =6400km)

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

$$g_h = \frac{g}{2}$$

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

$$\frac{1}{2} = (1+\frac{h}{R})^{-2}$$

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

$$\sqrt{2} = 1+\frac{h}{R}$$

$$\frac{h}{R} = \sqrt{2}-1$$

$$h = (\sqrt{2}-1)\,R = (1.414-1)\,6400 = 2650\ \text{km}$$

20.Calculate the value of acceleration due to gravity at a height equal to half of the radius of earth.

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

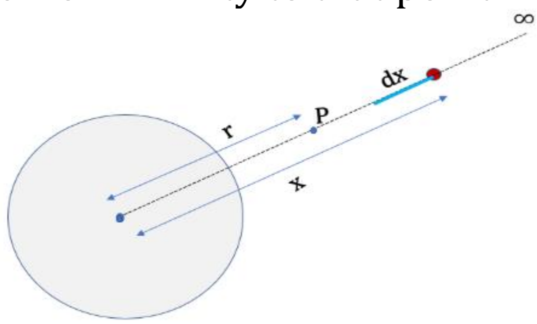
$$h = \frac{R}{2}$$

$$g_h = \frac{GM}{\left(R+\frac{R}{2}\right)^2} = \frac{GM}{\left(\frac{3}{2}R\right)^2}$$

$$= \frac{GM}{\frac{9}{4}R^2} = \frac{4}{9}\frac{GM}{R^2} = \frac{4}{9}\,g$$

21.Obtain the expression for gravitational potential energy at a point.

Gravitational potential energy at point is defined as the work done in displacing the particle from infinity to that point without acceleration.



Gravitational force on a mass m at a distance x

$$F = \frac{GMm}{x^2}$$

The work done to give a displacement dx to the mass

$$dW = Fdx$$

$$dW = \frac{GMm}{x^2}dx$$

Total work done to move the mass from ∞ to r

$$W = \int_{\infty}^{r} \frac{GMm}{x^2} dx$$
$$W = GMm \int_{\infty}^{r} \frac{1}{x^2} dx$$
$$W = \frac{-GMm}{r}$$

This work is is stored as gravitational PE in the body.

$$U = \frac{-GMm}{r}$$

22.Define gravitational potential at a point on earth. Obtain the expression for gravitational potential

The gravitational potential at a point is defined as the potential energy of a particle of unit mass at that point.

The gravitational Potential energy of a body of mass m at a distance r

$$U = \frac{-GMm}{r}$$

For unit mass m=1

So gravitational potential, $V = \frac{-GM}{r}$

23.What is escape speed(escape velocity)?

The minimum speed required for an object to reach infinity i.e. to escape from the earth's gravitational pull is called escape speed.

24.Derive the expression for escape speed.

$$\frac{1}{2} m v_i^2 - \frac{GMm}{r} = 0$$
$$\frac{1}{2} m v_i^2 = \frac{GMm}{R}$$
$$v_i^2 = \frac{2GM}{R}$$
$$v_e = \sqrt{\frac{2GM}{R}} \quad \text{or} \quad v_e = \sqrt{2gR}$$

25.Escape velocity is independent of ....(mass of the body/mass of the earth) Mass of the body.

26.Write thevalue of escape speed (or escape velocity) on the surface of earth . 11.2km/s

27.Moon has no atmosphere. Why?

The escape speed of moon is about 2.3 km/s. which is less than the average speed of gas molecules of moon. Thus gas molecules escape from surface of moon and it has no atmosphere.

28.What are sarth Satellites?

Earth satellites are objects which revolve around the earth.

29................. is the natural satellite of earth . Moon

30.What are the uses of artificial satellites?

Artificial satellites are used for telecommunication, geophysics and meteorology etc.

31.Derive the expression for orbital speed of a satellite

The speed with which a satellites revolves around earth is called orbital speed.

Consider a satellite of mass m in a circular orbit of a distance (R + h) from the centre of the earth.

$$F_{centripetal} = F_{gravitational}$$

$$\frac{mv^2}{R+h} = \frac{GMm}{(R+h)^2}$$

$$v^2 = \frac{GM}{(R+h)}$$

$$v_o = \sqrt{\frac{GM}{(R+h)}}$$

If the satellite is very close to earth (R+h) ≈R

$$v_o = \sqrt{\frac{GM}{R}} \quad \text{or} \quad v_o = \sqrt{gR}$$

32.Write the relation connecting escape velocity and orbital velocity

$$\text{Orbital Velocity}, v_0 = \sqrt{\frac{GM}{R}}$$

$$\text{Escape Velocity}, v_e = \sqrt{\frac{2GM}{R}}$$

$$v_e = \sqrt{2}\, v_o$$

Escape Velocity = $\sqrt{2}$ x Orbital Velocity

33.Derive the expression for period of a satellite

Period of a satellite is the time required for a satellite to complete one revolution around the earth in a fixed orbit.

$$\text{Period } T = \frac{\text{circumference of the orbit}}{\textit{orbital speed}}$$

$$T = \frac{2\pi\,(R+h)}{\sqrt{\frac{GM}{(R+h)}}}$$

$$T = 2\pi\sqrt{\frac{(R+h)^3}{GM}}$$

If the satellite is very close to earth (R+h) ≈R

$$T = 2\pi\sqrt{\frac{R^3}{GM}}$$

Chapter 8
Mechanical Properties of Solids

1.Define Elasticity

The property of a body, by virtue of which it tends to regain its original size and shape when the applied force is removed, is known as elasticity and such substances are called elastic .

Eg: Steel, Rubber

2.Which is more elastic, steel or rubber?

Steel

3.Define plasticity

Substances have no tendency to regain their previous shape on the removal of deforming force are called plastic and this property is called plasticity. Eg:Putty and mud

4.Define Stress

The restoring force per unit area is known as stress.

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

The SI unit of stress is N m^{-2} or pascal (Pa)

5.Define Strain

Strain is defined as the fractional change in dimension.

$$\text{Strain} = \frac{\textit{Change in dimension}}{\textit{Original dimension}}$$

Strain has no unit and dimension.

6.Wrte three types of stress and strain.

1. Longitudinal Stress and Longitudinal Strain
2. Shearing Stress and Shearing Strain
3. Hydraulic Stress and Hydraulic Strain (Volume Strain)

7.Define longitudinal stress

Longitudinal stress is defined as the restoring force per unit area when force is applied normal to the cross-sectional area of a cylinder.

$$\textbf{Longitudinal stress} = \frac{F}{A}$$

8. Define Longitudinal strain

Longitudinal strain is defined as the ratio of change in length(ΔL) to original length(L) of the body .

$$\text{Longitudinal strain} = \frac{\text{Change in length}}{\text{Original length}}$$

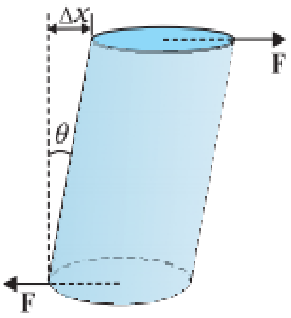
$$\textbf{Longitudinal strain} = \frac{\Delta L}{L}$$

9.Define shearing stress.

Shearing stress is defined as the restoring force per unit area when a tangential force is applied on the cylinder.

$$\text{Shearing stress} = \frac{F}{A}$$

10.Define Shearing strain.



Shearing strain is defined as the ratio of relative displacement of the faces Δx to the length of the cylinder L

$$\text{Shearing strain} = \frac{\Delta x}{L} = \tan\theta = \theta$$

11.Define hydraulic stress or volume stress

The restoring force per unit area of solid sphere, placed in the fluid is called hydraulic stress.

$$\text{Hydraulic stress} = \frac{F}{A} = -P \text{ (pressure)}$$

12.Define volume strain (hydraulic strain)

Volume strain(hydraulic strain) is defined as the ratio of change in volume (ΔV) to the original volume (V).

$$\text{Volume strain} = \frac{\text{Change in volume}}{\text{Original volume}}$$

$$\text{Volume strain} = \frac{\Delta V}{V}$$

13.State Hooke's Law

For small deformations the stress is directly proportional to strain. This is known as Hooke's law.

$$\text{Stress} \propto \text{Strain}$$

$$\frac{\text{Stress}}{\text{strain}} = k$$

The constant k is called Modulus of Elasticity.

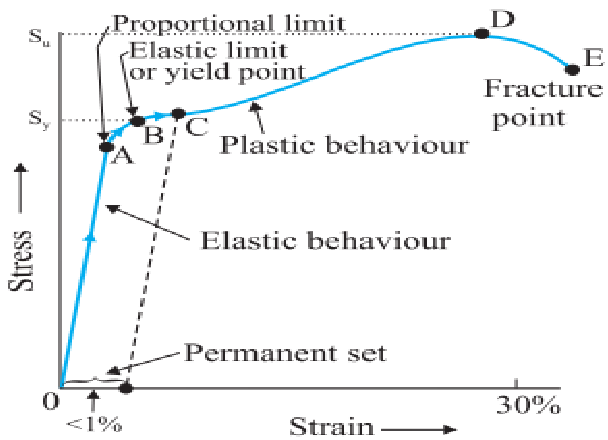
The SI unit of modulus of elasticity is N m^{-2} or pascal (Pa)

14.Define modulus of elasticity. Write its unit.

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

Unit = N m^{-2} or pascal (Pa)

15.The stress-strain curve for a metal is given in figure. Mark 1)Elastic limt (or) yield point 2) Fracture point 3) Proportional limit 4)Elastic region 5) Plastic region 6)permanent set 7) yield strength (S_y) 8) ultimate tensile strength (S_u)



16.Define young's eodulus(Y)

The ratio of longitudinal stress to longitudinal strain is defined as Young's modulus of the material .

$$Y=\frac{\text{longitudinal stress}}{\text{longitudinal strain}}$$

$$Y=\frac{\frac{F}{A}}{\frac{\Delta L}{L}}$$

$$Y=\frac{FL}{A\,\Delta L}$$

17.Youngs modulus of steel is ....(greater/less) than that of rubber

Greater than

18.Define shear modulus or rigidity modulus(G)

The ratio of shearing stress to the corresponding shearing strain is called the shear modulus or Rigidity modulus of the material .

$$G=\frac{\text{Shearing stress}}{\text{Shearing strain}}$$

$$G=\frac{\frac{F}{A}}{\frac{\Delta x}{L}}=\frac{\frac{F}{A}}{\theta}$$

$$G=\frac{F}{A\,\theta}$$

19.Define bulk modulus(B)

The ratio of hydraulic stress to the corresponding hydraulic strain is called bulk modulus.

$$B=\frac{\text{Hydraulic stress}}{\text{Hydraulic strain}}$$

$$B=\frac{\frac{F}{A}}{\frac{\Delta V}{V}}=\frac{-P}{\frac{\Delta V}{V}}$$

$$\mathbf{B=\frac{-PV}{\Delta V}}$$

20.Define compressibility(k)

The reciprocal of the bulk modulus is called compressibility.

$$k=\frac{1}{B}$$

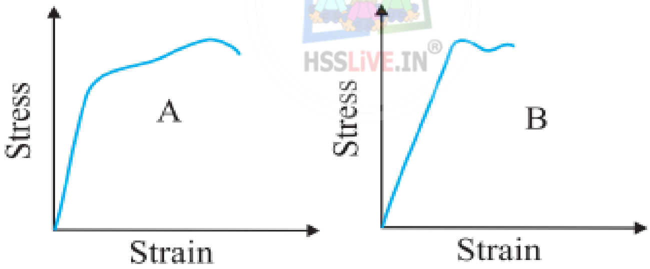
$$\mathbf{k=\frac{-1}{P}\frac{\Delta V}{V}}$$

- The compressibility is the least for solids and the most for gases.
- The bulk modulus is the least for gases and the most for solids.

21.Why steel is preferred in heavy-duty machines and in structural designs?

Young's modulus of steel is greater than that of copper, brass and aluminium. So steel is more elastic than copper, brass and aluminium. So steel is preferred in heavy-duty machines and in structural designs

22.The stress-strain graphs for materials A and B are shown in Figure.



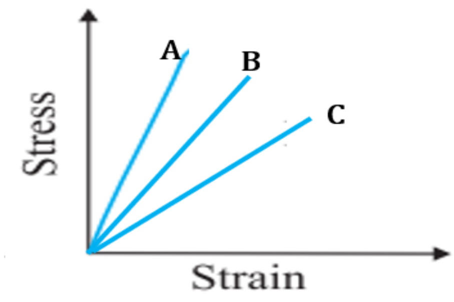
(a) Which of the materials has the greater Young's modulus?
(b) Which of the two is the stronger material?
(c) Which of the two materials is more ductile?

(a) Young's modulus $Y=\frac{\text{stress}}{\text{strain}}$ = slpoe of the graph.
Slope of graph for material A is greater than that of B.
So materials A has the greater Young's modulus.

(b) Strength of a material is determined by the amount of stress required to cause fracture.
The fracture point is greater for material A.
So material A is stronger than B

(c) The fracture point is far apart for material A than B.
So material A is more ductile than B.

23..The stress-strain graph for three materials A B and C are shown below



Which is more elastic A ,B or C. Justify your answer.

Material A is more elastic

Modulus of elasticity $=\frac{\text{stress}}{\text{strain}}$ = slpoe of the graph

Slope of graph for material A is greater than that of B and C

So material A is more elstic.

24.A structural steel rod has a radius of 10 mm and a length of 1.0 m. A 100 kN force stretches it along its length. Calculate (a) stress, (b) elongation, and (c) strain on the rod. Young's modulus, of structural steel is 2.0×10^{11} N m^{-2}

(a) $\text{stress}=\frac{F}{A} = \frac{F}{\pi r^2}$

$$= \frac{100\ x\ 10^3}{3.14\ x\ (10\ x\ 10^{-3})^2} = \frac{100\ x\ 10^3}{3.14\ x\ 10^{-4}}$$

$$=3.18\ \text{x}10^8\ \text{N}m^{-2}$$

(b) $\text{Y}=\frac{FL}{\text{A}\ \Delta\text{L}}$

$$\Delta\text{L} = \frac{(\frac{F}{A})L}{\text{Y}} = \frac{3.18\ \text{x}10^8\ x\ 1}{2\times 10^{11}}$$

$$= 1.59\ \text{x}10^{-3}\ \text{m}$$

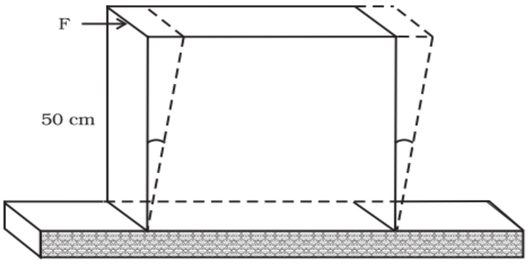
$$= 1.59\ \text{mm}$$

(c) $\text{Strain} = \frac{\Delta\text{L}}{L}$

$$= \frac{1.59\ \text{x}10^{-3}}{1}$$

$$= 1.59\ \text{x}10^{-3}\ \text{m}$$

25.A square lead slab of side 50 cm and thickness 10 cm is subject to a shearing force (on its narrow face) of 9.0×10^4 N. The lower edge is riveted to the floor. How much will the upper edge be displaced? Given shear modulus, G =$5.6 \times 10^9\text{Nm}^{-2}$



$$\text{Stress} = \frac{F}{A} = \frac{9.0 \times 10^4}{0.5 \times 0.1} = \frac{9.0 \times 10^4}{0.05}$$
$$= 1.80 \times 10^6 \text{ N } m^{-2}$$
$$G = \frac{\text{stress}}{\frac{\Delta x}{L}}$$
$$\Delta x = \frac{stress \; x \; L}{G}$$
$$= \frac{1.80 \times 10^6 \; x \; 0.5}{5.6 \times 10^9} = 1.6 \times 10^{-4} \text{ m} = 0.16 \text{ mm}$$

26.The average depth of Indian Ocean is about 3000 m. Calculate the fractional compression, ΔV/V, of water at the bottom of the ocean, given that the bulk modulus of water is 2.2×10^9 N m^{-2}. (Take g = 10 m s^{-2})

$$G = \frac{-P}{\frac{\Delta V}{V}}$$
$$\frac{\Delta V}{V} = \frac{P}{G}$$
$$P = h\rho g = 3000 \text{ x}1000 \; x10 = 3x10^7 \text{ N } m^{-2}$$
$$\frac{\Delta V}{V} = \frac{3x10^7}{2.2 \times 10^9} = 1.36 \times 10^{-2}$$

27.Define Poisson's ratio

The ratio of lateral strain to longitudinal strain is called Poisson's ratio.

$$\text{Poisson's Ratio } \sigma = \frac{Lateral\ Strain}{Longitudnal\ Strain}$$
$$\sigma = \frac{\frac{\Delta d}{d}}{\frac{\Delta L}{L}}$$
$$\sigma = \frac{\Delta d}{\Delta L} \; x \; \frac{L}{d}$$

Poisson's ratio has no unit and dimension.

28.Cranes used for lifting and moving heavy loads have a thick metal rope . Why?

This is due to the fact that metals have greater youngs modulus.

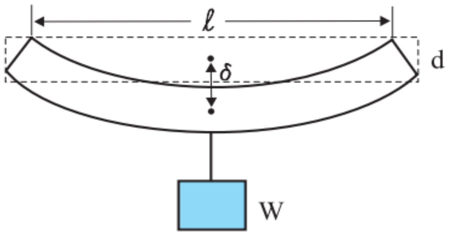
29.The metal ropes used in cranes are always made of a number of thin wires braided together.Why?

In cranes thicker rope of radius about 3 cm is recommended. A single wire of this radius would practically be a rigid rod. So the ropes are always made of a number of thin wires braided together, like in pigtails, for ease in manufacture, flexibility and strength.

30.The maximum height of a mountain on earth is ~10 km. Why?

The height of mountain is limited by the elastic properties of rocks.

31.Write the expression for bending δ produced in the beam shown below. How can we reduce bending?



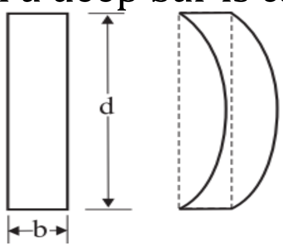
$$\delta = \frac{W\,l^3}{4bd^3Y} \qquad (W=mg)$$

The bending reduces by

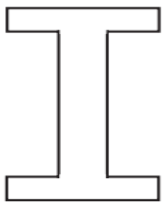
- Using a material with a large Young's modulus Y
- Increasing the breadth b of the beam
- Increasing depth d of the beam.

32.What is buckling?

The sidewise bending of a deep bar is called buckling.



33.Why beams with cross-sectional shape of I is used for construction of bridges?



- This sections prevents buckling of beams
- This section provides a large load bearing surface and enough depth to prevent bending.
- This shape reduces the weight of the beam without sacrificing the strength This shape reduces the cost.

Chapter 9
Mechanical Properties Of Fluids

1.Write two basic difference between Liquids and Gases

- A liquid is incompressible whereas gas is compressible
- A liquid has a free surface of its own ,but gas has no free surface.

2.Define pressure.

The normal force(F) exerted by a fluid on an area A is called pressure.

$$\text{Pressure, } P = \frac{F}{A}$$

Pressure is a scalar quantity.

3.What do you mean by atmospheric pressure?

The pressure exerted by the atmosphere at sea level.

$$1 \text{ atm} = 1.013 \times 10^5 \text{ Pa.}$$

4.Define density?

Density ρ for a fluid of mass m occupying volume V is given by

$$\rho = \frac{m}{V}$$

5.Define relative density

The relative density of a substance is the ratio of its density to the density of water at 4^0C.

$$\text{Relative density} = \frac{\text{Density of substance}}{\text{Density of water at } 4^0\text{C}}$$

It is a dimensionless positive scalar quantity.

6.Write the expression for absolute pressure P, at depth below the surface of a liquid open to the atmosphere.

$$\text{Absolute Pressure, } P = P_a + \rho gh$$

7.Write the expreassion for gauge pressure

$$\text{Gauge pressure, } P - P_a = \rho gh$$

8.What is the pressure on a swimmer 10 m below the surface of a lake?

$h = 10$ m

$\rho = 1000 \text{ kg m}^{-3}$ Take $g = 10 \text{ m s}^{-2}$

$$P = P_a + \rho gh$$
$$= 1.01 \times 10^5 + 1000 \times 10 \times 10$$
$$= 1.01 \times 10^5 + 1 \times 10^5$$
$$= 2.01 \times 10^5 \text{ Pa} \approx 2 \text{ atm}$$

9.At a depth of 1000 m in an ocean
(a) what is the absolute pressure?
(b) What is the gauge pressure?
(The density of sea water is 1.03×10^3 kg m^{-3}, g = 10m s^{-2})

$h = 1000$ m , $\rho = 1.03 \times 10^3$ kg m^{-3}

(a) Absolute pressure, $P = P_a + \rho gh$

$= 1.01 \times 10^5 + 1.03 \times 10^3 \times 10 \times 1000$

$= 1.01 \times 10^5 + 103 \times 10^5$

$= 104.01 \times 10^5$ Pa ≈ 104 atm

(b) Gauge pressure , $P - P_a = \rho gh$

$= 1.03 \times 10^3 \times 10 \times 1000$

$= 103 \times 10^5$ Pa ≈ 103 atm

10.The device used to measure Atmospheric Pressure.

Mercury barometer is used to measure Atmospheric Pressure.

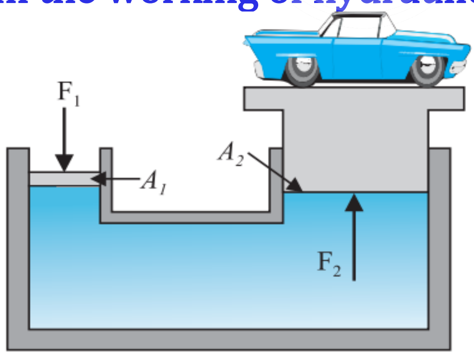
11.The device used to measure Guage pressure or pressure differences

An open-tube manometer is a used for measuring Guage pressure or pressure differences.

12.State Pascal's law for transmission of fluid pressure.

Whenever external pressure is applied on any part of a fluid contained in a vessel, it is transmitted undiminished and equally in all directions.

13.Briefly explain the working of hydraulic lift.



The pressure on smaller piston

$$P = \frac{F_1}{A_1} \text{-------------}(1)$$

This pressure is transmitted equally to the larger cylinder with a larger piston of area A_2 producing an upward force F_2.

$$P = \frac{F_2}{A_2} \text{-------------}(2)$$

From eq(1) and (2) $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

$$\mathbf{F_2 = F_1 \frac{A_2}{A_1}}$$

14. A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000kg. The area of cross section of the piston carrying 425 cm^2. What maximum pressure would the smaller piston have to bear?

Pressure on two two pistons will be same.

$$P= \frac{F_1}{A_1}=\frac{F_2}{A_2}$$

$$P = \frac{F_2}{A_2} =\frac{mg}{A_2}$$

$$=\frac{2000\ x\ 9.8}{425\ x 10^{-4}} =6.92\ x 10^5\ Nm^{-2} \text{ or Pa}$$

15.Two syringes of diffrent cross sections (without needles) filled with water are connected with a tightly fitted rubber tube filled with water. Diameters of the smaller piston and larger piston are 1.0 cm and 3.0 cm respectively. Find the force exerted on the larger piston when a force of 10 N is applied to the smaller piston.

$$F_2 = F_1 \frac{A_2}{A_1}$$

$$F_2 = 10\ x \frac{\pi\ x\ (1.5\ x\ 10^{-2})^2}{\pi\ x\ (0.5\ x\ 10^{-2})^2}$$

$$= 10\ x 9\ = 90\ N$$

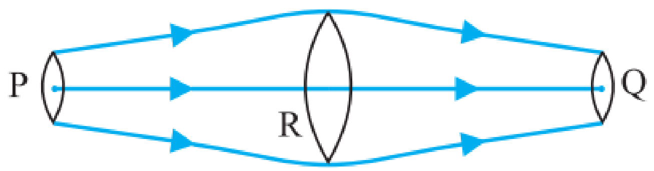
16.What do you mean by streamline flow (Steady Flow)?

The flow of the fluid is said to be steady if at any given point, the velocity of each passing fluid particle remains constant in time.

17.What is turbulent flow?

Beyond a limiting speed called critical speed, the flow of fluid loses steadiness and is called turbulent flow.

18.Obtain the expression for equation of continuity for streamline flow of a fluid.



The mass of liquid flowing out = The mass of liquid flowing in

$$\rho_P A_P v_P \Delta t = \rho_Q A_Q v_Q \Delta t = \rho_R A_R v_R \Delta t$$

If the fluid is incompressible $\rho_P = \rho_Q = \rho_R$

$$A_P v_P = A_Q v_Q = A_R v_R$$

$$Av = \text{constant}$$

19.The equation of continuity and it is a statement of conservation of ……………. in flow of incompressible fluids.

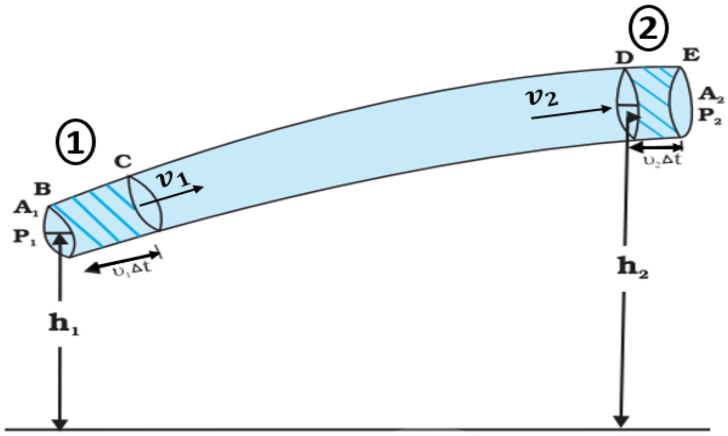
mass

20. State and prove Bernoulli's Principle

Bernoulli's principle states that as we move along a streamline, the sum of the pressure , the kinetic energy per unit volume and the potential energy per unit volume remains a constant.

$$\mathbf{P + \frac{1}{2}\rho v^2 + \rho gh = constant}$$

Proof



The total work done on the fluid is

$$W_1 + W_2 = P_1\Delta V - P_2\Delta V$$

$$\mathbf{W_1 + W_2 = (P_1 - P_2)\Delta V}\text{-----------------}(1)$$

The change in its kinetic energy is

$$\mathbf{\Delta K = \frac{1}{2}m(v_2^2 - v_1^2)}\text{ ---------------}(2)$$

The change in gravitational potential energy is

$$\mathbf{\Delta U = mg(h_2 - h_1)}\text{------------------}(3)$$

By work – energy theorem

$$W_1 + W_2 = \Delta K + \Delta U$$

$$\mathbf{(P_1 - P_2)\Delta V = \frac{1}{2}m(v_2^2 - v_1^2) + mg(h_2 - h_1)}\text{-------------}(4)$$

Divide each term by ΔV to obtain $\left(\frac{m}{\Delta V} = \rho\right)$

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) + \rho g(h_2 - h_1)$$

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho gh_2 - \rho gh_1$$

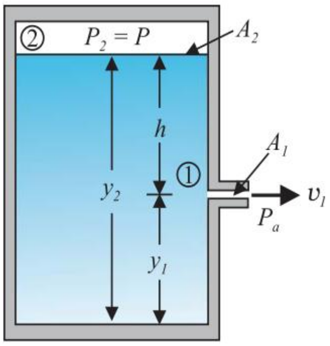
$$P_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gh_2$$

$$\mathbf{P + \frac{1}{2}\rho v^2 + \rho gh = constant}$$

21.State Torricelli's law of speed of efflux of fluid

Torricelli's law states that the speed of efflux of fluid through a small hole at a depth h of an open tank is equal to the speed of a freely falling body i.e, $\sqrt{2gh}$

22.Prove Torricelli's law of speed of efflux of fluid.



According to Bernoulli principle

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Here $v_2 = 0$.

$$P_a + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P + \rho g y_2$$

$$\frac{1}{2}\rho v_1^2 = \rho g(y_2 - y_1) + P - P_a$$

$$y_2 - y_1 = h$$

$$\frac{1}{2}\rho v_1^2 = \rho g h + P - P_a$$

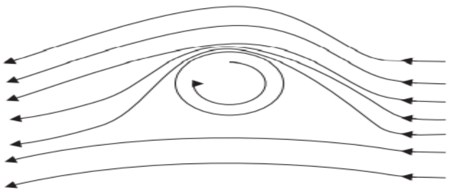
$$v_1^2 = 2gh + \frac{2(P - P_a)}{\rho}$$

$$v_1 = \sqrt{2gh + \frac{2(P - P_a)}{\rho}}$$

If the tank is open to the atmosphere, then $P = P_a$

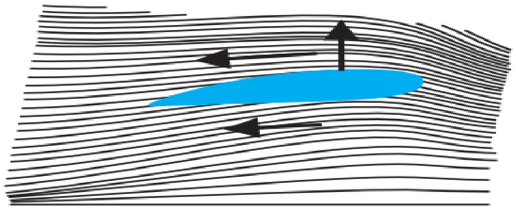
$$v_1 = \sqrt{2gh}$$

23.Explain Magnus Effect.



The relative velocity of air above the ball is larger and below it is smaller. This difference in the velocities of air results in the pressure difference between the lower and upper faces and there is a net upward force on the ball. This dynamic lift due to spining is called Magnus effect.

24.What is an aerofoil and how a dynamic lift is produced on aircraft wing

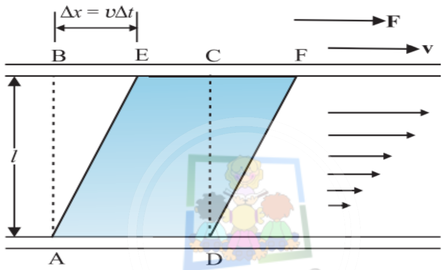


Aerofoil is a solid piece shaped to provide an upward dynamic lift when it moves horizontally through air. When the aerofoil moves against the wind, the flow speed of air on top is higher than that below it. There is an upward force resulting in a dynamic lift of the wings and this balances the weight of the plane.

25.Define viscosity

The internal frictional force that acts when there is relative motion between layers of the liquid is called viscosity.

26.Obtain the expression for Coefficient of viscosity(η)



The coefficient of viscosity(η)for a fluid is defined as the ratio of shearing stress to the strain rate.

$$\eta = \frac{\text{Shearing stress}}{\text{Strain rate}} = \frac{\frac{F}{A}}{\frac{v}{l}}$$

$$\eta = \frac{Fl}{vA}$$

27.The viscosity of liquids .... with temperature while the viscosity of gases .... in the case of gases.

Decreases, increases

28.State Stokes' Law

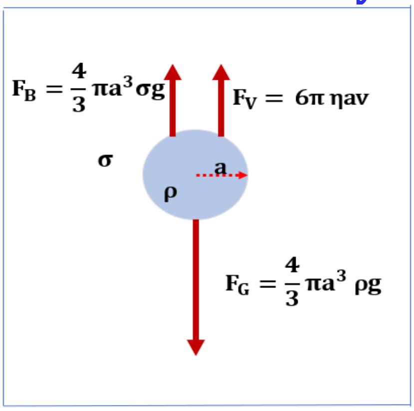
Stokes' law states that the viscous drag force F on a sphere of radius a moving with velocity v through a fluid of coefficient of viscosity η is,

$$F = 6\pi\eta av$$

29.What terminal velocity?

For an object falls through a viscous medium, when viscous force plus buoyant force becomes equal to the weight of the body, the net force and acceleration become zero. Then the object descends with a constant velocity called terminal velocity.

30.Obtain expression for terminal velocity.



Consider a raindrop in air. The forces acting on the drop are

1. Weight acting downwards , $F_G = \frac{4}{3}\pi a^3 \rho g$ (mg)
2. Buoyant force acting upwards, $F_B = \frac{4}{3}\pi a^3 \sigma g$
3. Viscous force, $F_V = 6\pi\eta a v$

In equilibrium,

$$6\pi\eta a v + \frac{4}{3}\pi a^3 \sigma g = \frac{4}{3}\pi a^3 g\rho$$

$$6\pi\eta a v = \frac{4}{3}\pi a^3 (\rho - \sigma) g$$

Terminal velocity , $\mathbf{v_t = \frac{2a^2 (\rho - \sigma) g}{9\eta}}$

31.The terminal velocity of a copper ball of radius 2.0 mm falling through a tank of oil at 20^0C is 6.5 cm s^{-1}. Compute the viscosity of the oil at 20^0C. Density of oil is 1.5×10^3 kg m^{-3}, density of copper is 8.9×10^3 kg m^{-3}.

$v_t = 6.5 \times 10^{-2}\ ms^{-1}$ $\rho = 8.9 \times 10^3$ kg m^{-3}
$a = 2 \times 10^{-3}$ m $\sigma = 1.5 \times 10^3$ kg m^{-3}
$g = 9.8 m\ s^{-2}$,

$$v_t = \frac{2a^2 (\rho - \sigma) g}{9\eta}$$

$$\eta = \frac{2a^2 (\rho - \sigma) g}{9 v_t}$$

$$\eta = \frac{2 \text{ x } (2 \times 10^{-3})^2 (8.9 \times 10^3 - 1.5 \times 10^3) \text{x} 9.8}{9 \text{ x } 6.5 \times 10^{-2}}$$

$$\eta = 9.9 \times 10^{-1} \text{ kg } m^{-1} s^{-1}$$

32.Write the Reynolds Number.

$$\mathbf{R_e = \frac{\rho v d}{\eta}}$$

$R_e < 1000$ – The flow is streamline or laminar.
$R_e > 2000$ – The flow is turbulent .
R_e between 1000 and 2000-The flow becomes unsteady .

33.Define surface tension

Surface tension is a force per unit length (or surface energy per unit area) acting in the plane of the interface between the plane of the liquid and any other substance.

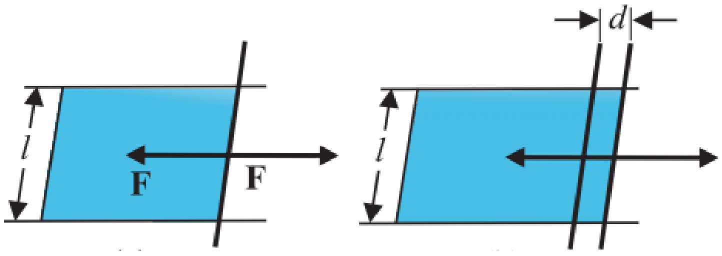
$$\text{Surface Tension, } S = \frac{\text{Force}}{\text{Length}}$$

- The SI Unit is Nm^{-1}
- Dimensional formula is MT^{-2}.

34.The surface tension of a liquid .... with temperature.

decreases

35.Show that surface tension is equal to surface energy per unit area.



Inorder to keep the bar in its original position some work has to be done against this inward full.

$$W = F \times d \text{----------(1)}$$

If the surface energy of the film is S per unit area, the extra area is $2dl$ (film has two sides),

$$\text{The extra surface energy} = S \times 2dl \text{ ------------(2)}$$

$$\text{The extra surface energy} = \text{work done}$$

$$S \times 2dl = Fd$$

$$S = \frac{F}{2l} = \text{surface tension}$$

36.Some effects of surface Tension

- Oil and water do not mix.
- Water wets you and me but not ducks.
- Mercury does not wet glass but water sticks to it.
- Oil rises up a cotton wick, inspite of gravity.
- Sap and water rise up to the top of the leaves of the tree.
- Hairs of a paint brush do not cling together when dry and even when dipped in water but form a fine tip when taken out of it.

37.Define angle of contact

The angle between tangent to the liquid surface at the point of contact and solid surface inside the liquid is termed as angle of contact(θ)

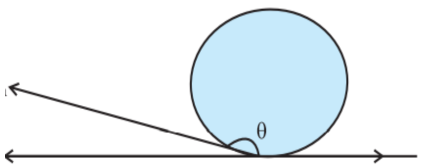
- Angle of contact is obtuse for Water on a waxy or oily surface, Mercury on any surface.
- Angle of contact is acute for Water on glass or on plastic, Kerosene oil on virtually anything .

38.Draw the angle of contact when

a) the liquid wets the solid.

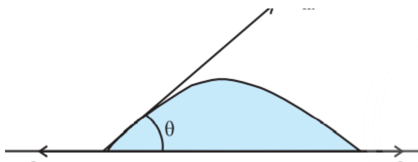
b) the liquid does not wet the solid.

a)



When angle of contact, θ is an obtuse angle(greater than 90)

b)



When angle of contact,θ is an acute angle (less than 90).

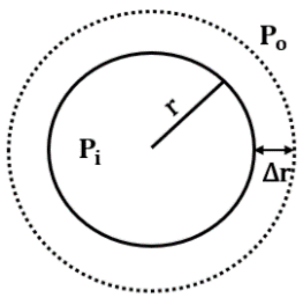
39.Why are small drops and bubbles spherical?

Due to surface tension ,liquid surface has the tendency to reduce surface area. For a given volume sphere has minimum surface area. So small drops and bubbles are spherical.

40.Why are large drops and bubbles not spherical, but flattened?

For large drops the effect of gravity predominates that of surface tension and they get flattened.

41.Derive the expression for excess pressure inside a spherical drop



Work done in expansion= Force x Displacement

= Excess pressure x Area x Displacement

$W = (P_i - P_o) \times 4\pi r^2 \times \Delta r$ -----------------(1)

This workdone is equal to the increase in surface energy

Extra Surface energy = Surface tension x Increase in surface area

Extra surface energy = $S \times 8\pi r\Delta r$ -----------------(2)

The workdone = extra surface energy

$(P_i - P_o) \times 4\pi r^2 \times\Delta r = 8\pi r\Delta r\, S$ -------------(3)

$$\mathbf{(P_i - P_o) = \frac{2S}{r}}$$

42.Write the expression for excess pressure inside a liquid bubble

A bubble has two free surfaces.

$$(P_i - P_o) = 2\text{x}\ \frac{2S}{r}$$

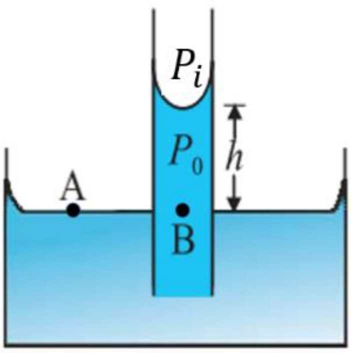
$$\mathbf{(P_i - P_o) = \frac{4S}{r}}$$

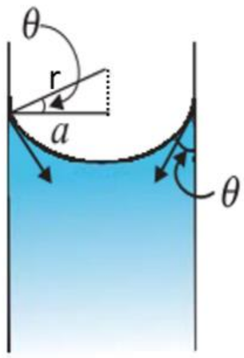
43.What is capillary rise? What is the phenomenon responsible for it?

Water rises up in a capillary tube dipped in a liquid in spite of gravity. This is called capillary rise.

Surfacetesion is responsible for capillary rise.

44.Obtain an expression for capillary rise





The excess pressure on the concave meniscus

$$(P_i - P_o) = \frac{2S}{r}$$

$$\cos\theta = \frac{a}{r}\ ,\ r = \frac{a}{\cos\theta}$$

$$(P_i - P_o) = \frac{2S}{\frac{a}{\cos\theta}}$$

$$(P_i - P_o) = \frac{2S\cos\theta}{a}\ \text{----------------(1)}$$

Consider two points A and B in the same horizontal level i.e, the points are at the same pressure.

$$\text{Pressure at A} = P_i$$
$$\text{Pressure at B} = P_o + h\,\rho\,g$$
$$P_i = P_o + h\,\rho\,g$$
$$P_i - P_o = h\,\rho\,g \text{---------------}(2)$$

From eq(1) and (2)

$$h\,\rho\,g = \frac{2S\cos\theta}{a}$$
$$h = \frac{2S\cos\theta}{\rho\,g a}$$

44.What is capillary depression?

When liquid level lower in the capillary tube dipped in a liquid ,it is called capillary fall or capillary depression.

45.Why mercury shows capillary depression?

For mercury, angle of contact θ will be obtuse . Then cos θ is negative and hence value of h will be negative. So mercury shows capillary depression.

46.Find the capillary rise when a capillary tube of radius 0.05 cm is dipped vertically in water. Surface tension for water is 0.073Nm^{-1} .Density of water is 1000 kgm^{-3}.

$$h = \frac{2S\cos\theta}{\rho\,g a}$$

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

$$h = \frac{2S}{\rho\,g a}$$
$$h = \frac{2x\ 0.073}{1000\ x\ 9.8\ x\ 0.05\ x 10^{-3}}$$
$$h = 2.98 \times 10^{-2}\ \text{m} = 2.98\ \text{cm}.$$

47.How soaps and detergents helps to remove dirts from clothes

The molecules of detergents produce a water-oil interface which reduces the surface tension (water-oil) and dirt can be removed by running water.

Chapter 10
Thermal Properties of Matter

1.Write the relation connecting temperature on Fahrenheit scale and Celsius scales .

$$\frac{t_F - 32}{180} = \frac{t_C}{100}$$

2.Write the relation connecting temperature on Kelvin and Celsius scales .

$$T = t_C + 273.1$$

3.Temperature of a normal human body is 98.6^{0}F. What is the corresponding temperature in Celsius scale?

$$\frac{98.6 - 32}{180} = \frac{t_C}{100}$$

$$t_C = \frac{(98.6-32)x100}{180} = 37^0C$$

4.State Boyle's law

At constant temperature , the pressure of a quantity of gas is inversely proportional to volume.

$$P \propto \frac{1}{V}$$

$$PV = constant.$$

5.State Charles' law

At constant pressure , the volume of a quantity of gas is directly proportional to temperature .

$$V \propto T$$

$$\frac{V}{T} = constant$$

6.Write Ideal gas equation

$$PV = \mu RT$$

where, μ is the number of moles in the sample of gas.
R is called universal gas constant: $R = 8.31\ J\ mol^{-1}\ K^{-1}$

7.What do you mean by absolute zero temperature or zero kelvin (OK)

The minimum temperature for an ideal gas is called Absolute temperature or zero kelvin(OK). This temperature is found to be – 273.15 °C

8.What is thermal expansion

The increase in the dimensions of a body due to the increase in its temperature is called thermal expansion.

9.Write the expression for coefficient of linear expansion

$$\alpha_l = \frac{\Delta l}{l\,\Delta T}$$

10.Write the expression for coefficient of area expansion

$$\alpha_a = \frac{\Delta A}{A\,\Delta T}$$

11.Write the expression for coefficient of volume expansion

$$\alpha_v = \frac{\Delta V}{V\Delta T}$$

12. Obtain the relation between α_l and α_a

$$\alpha_a = \frac{\Delta A}{A\,\Delta T}$$

$\Delta A = (l + \Delta l)^2 - l^2$

$\Delta A = 2\, l\, \Delta l$ (Neglecting term $(\Delta l)^2$)

$A = l^2$

$$\alpha_a = \frac{2\, l\, \Delta l}{l^2 \Delta T}$$

$$\alpha_a = 2\, \frac{\Delta l}{l\,\Delta T}$$

$$\frac{\Delta l}{l\,\Delta T} = \alpha_l$$

$$\boldsymbol{\alpha_a = 2\,\alpha_l}$$

13.Relation between α_l and α_v

$$\alpha_v = \frac{\Delta V}{V\Delta T}$$

$\Delta V = (l + \Delta l)^3 - l^3$

$\Delta V = 3\, l^2\, \Delta l$ (Neglecting terms $(\Delta l)^2$ and $(\Delta l)^3$)

$V = l^3$

$$\alpha_v = \frac{3\, l^2\, \Delta l}{l^3 \Delta T}$$

$$\alpha_v = 3\, \frac{\Delta l}{l\,\Delta T}$$

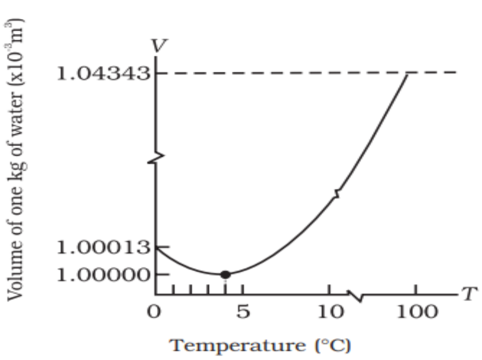
$$\frac{\Delta l}{l\,\Delta T} = \alpha_l$$

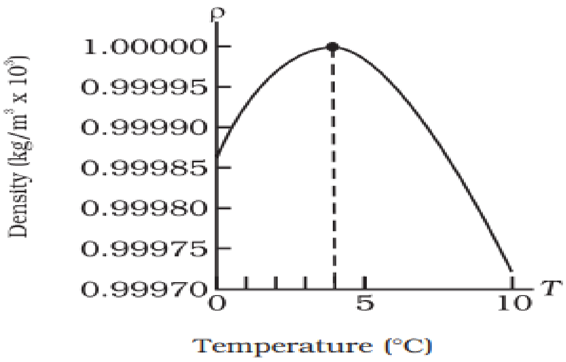
$$\boldsymbol{\alpha_v = 3\,\alpha_l}$$

14.What is the ratio of α_l , α_a and α_v

$$\alpha_l : \alpha_a : \alpha_v = 1 : 2 : 3$$

15.Based on the graph given below explain the anomalous expansion of water.





Water exhibits an anomalous behavour; it contracts on heating from 0 °C to 4 °C. When it is heated after 4 °C ,it expands like other liquids.

This means that water has minimum volume and hence maximum density at 4 °C .

16.Why the bodies of water, such as lakes and ponds, freeze at the top first?

This is due to anomalous expansion of water. water has minimum volume and hence maximum density at 4 °C .

As a lake cools toward 4 °C, water near the surface becomes denser, and sinks. Then the warmer, less dense water near the bottom rises. When this layer cools to 0 °C, it freezes, and being less dense, remain at the surfaces.

17.Define heat capacity

Heat capacity (S) of a substance is the amount of heat required to raise the temperature of the substance by one unit.

$$S = \frac{\Delta Q}{\Delta T}$$

Unit is JK^{-1}

18.Define specific heat capacity

Specific heat capacity (s) of a substance is the amount of heat required to raise the temperature of unit mass of the substance by one unit.

$$s = \frac{1}{m}\frac{\Delta Q}{\Delta T}$$

Unit is $Jkg^{-1}K^{-1}$

19.Define molar specific heat capacity

Molar Specific heat capacity (C) of a substance is the amount of heat required to raise the temperature of one mole of the substance by one unit.

$$C = \frac{1}{\mu}\frac{\Delta Q}{\Delta T}$$ Unit is $Jmol^{-1}K^{-1}$

20.Why gases have two specific heat capacities ?

As gas is compressible, heat transfer can be achieved by keeping either pressure or volume constant. So gases have two types of molar specific heat capacities,C_p and C_v

21.efine molar specific heat capacity at constant pressure C_p

Molar specific heat capacity at constant pressure of a substance is the amount of heat required to raise the temperature of one mole of the substance by one unit keeping its pressure constant.

$$C_p = \frac{1}{\mu}\left(\frac{\Delta Q}{\Delta T}\right)_p$$

22.Define molar specific heat capacity at constant volume C_v

Molar specific heat capacity at constant volume of a substance is the amount of heat required to raise the temperature of one mole of the substance by one unit keeping its volume constant.

$$C_v = \frac{1}{\mu}\left(\frac{\Delta Q}{\Delta T}\right)_v$$

23.Write the specific heat capacity of water.

4186 is $Jkg^{-1}K^{-1}$

24.Water is used as a coolant in automobile radiators as well as a heater in hot water bags.Why?

Specific heat capacity of water is very high equal to 4186 is $Jkg^{-1}K^{-1}$.

25.Measurement of heat is called.................

Calorimetry

26.A **device in which heat measurement can be made is called a ....**

Calorimeter.

27.**Write the names of following phase trasitions.**

Change of state	
Solid to Liquid	Melting
Liquid to Solid	Fusion
Liquid to Gas	Vaporisation
Gas to Liquid	Condensation
Solid to Gas	Sublimation

28.The temperature at which the solid and the liquid states of the substance coexist in thermal equilibrium with each other is called its -------------

melting point.

29.Melting point ------------ with increase in pressure.

decreases

30.The temperature at which the liquid and the vapour states of the substance coexist in thermal equilibrium is called its--------------

boiling point.

31. The boiling point increases with increase in pressure and decreases with decreases in pressure.

32 .Cooking is difficult on hills. Give reason.

The boiling point decreases with decreases in pressure. At high altitudes, atmospheric pressure is lower, boiling point of water decreases as compared to that at sea level. So cooking is difficult.

33.Cooking is faster using a pressure cooker. Give reason

The boiling point increases with increase in pressure.
Boiling point is increased inside a pressure cooker by increasing the pressure. Hence cooking is faster.

34.Define Sublimation. Give an example of a substance that sublime.

The change from solid state to vapour state without passing through the liquid state is called sublimation.

Eg: Dry ice (solid CO_2) , Iodine ,Camphor

35.Define Latent Heat

The amount of heat per unit mass transferred during change of state of the substance is called latent heat of the substance for the process.

$$L = \frac{Q}{m}$$

SI unit of Latent Heat is $J\,kg^{-1}$

36.Define Latent Heat of Fusion (L_f)

The latent heat for a solid -liquid state change is called the latent heat of fusion (L_f) or simply heat of fusion.

L_f of water $= 3.33 \times 10^5\ J\,kg^{-1}$.

37.Define Latent Heat of Vaporisation (L_v)

The latent heat for a liquid-gas state change is called the latent heat of vaporisation
(L_v) or heat of vaporisation.

L_v of water$= 22.6 \times 10^5\ J\,kg^{-1}$

38. Calculate the amount of heat energy required to convert10kg of water at 100^0 C to steam at 100^0 C.

$$L_V = \frac{Q}{m}$$

$$Q = L_V m$$

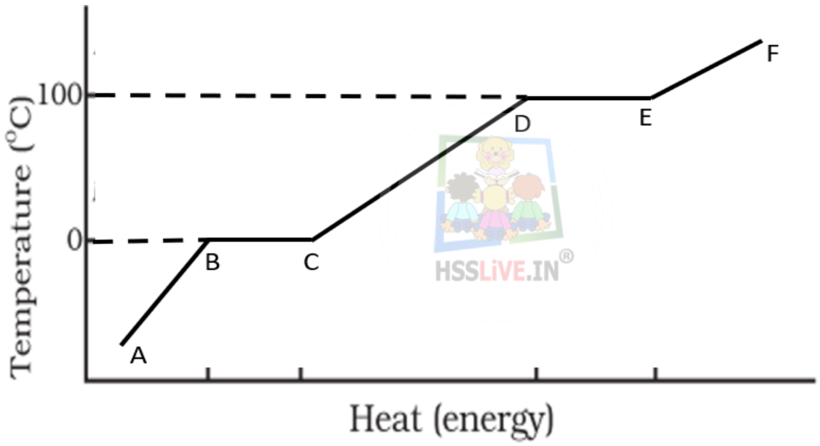
$$Q = 22.6 \times 10^5 \text{ x } 10$$

$$Q = 22.6 \times 10^6\ J$$

39.Why burns from steam are usually more serious than those from boiling water?

For water, the latent heat of vaporisation is $L_V = 22.6 \times 10^5$ J kg^{-1}.
So, steam at 100 °C carries 22.6×10^5J kg^{-1}more heat than water at 100 °C. This is why burns from steam are usually more serious than those from boiling water.

40.The graph given below represents the temperature versus heat for water at 1 atm pressure. Answer the following questions.



(i)Fill up the table

Graph	Process	Phase(state)
BC	------------ Ans:Melting	------------- Ans: solid + liquid
DE	------------ Ans: Vaporisation	-------------Ans: liquid + gas

Graph	Phase
AB	---------- Ans: Solid (ice)
CD	---------- Ans: Liquid(water)
EF	---------- Ans: Gas(steam)

(ii)The heat energy corresponding to BC is called ------------

Latent heat of fusion

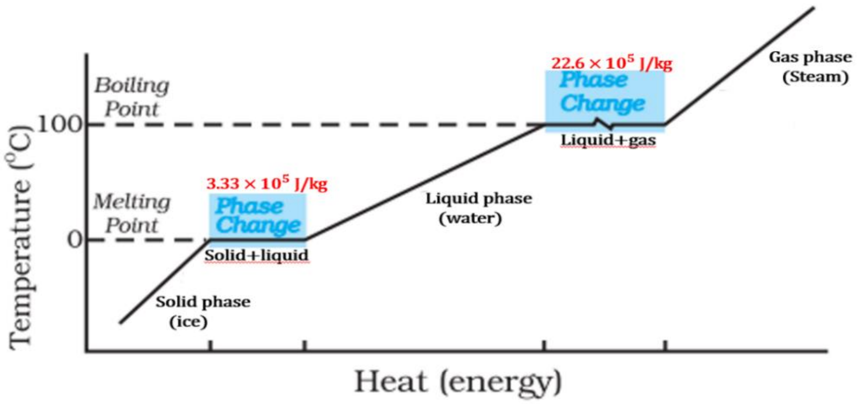
(iii)The heat energy corresponding to DE is called ------------

Latent heat of Vaporisation

(iv)The slope of AB and CD are different.Why?

Different slopes indicates that specific heat capacity of ice and water are different.

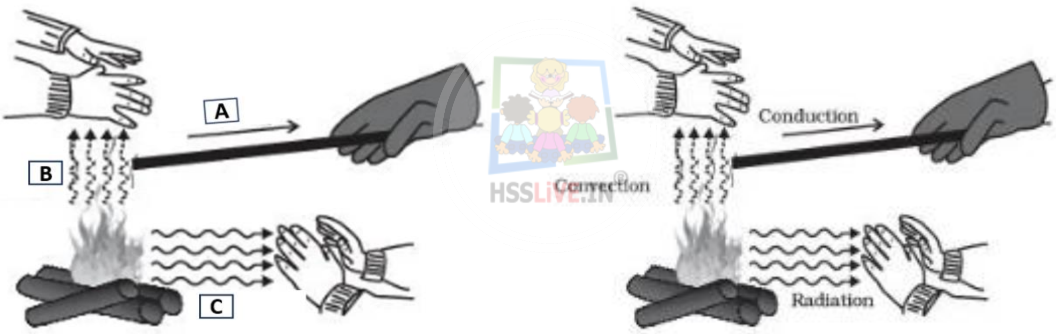
- When slope of graph is less, it indicates a high specific heat capacity .
- Slope of CD is less than that of AB ,i.e., specific heat capacity of water is greater than that of ice.



41 a).Write different modes of heat transfer.

conduction, convection and radiation.

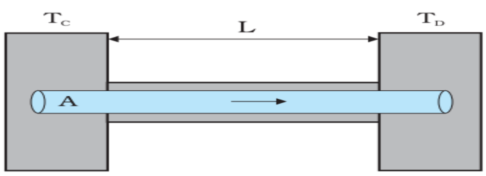
b)Identify the modes of heat transfer and ,B and C.



42.What is conduction?

Conduction is the mechanism of transfer of heat between two adjacent parts of a body because of their temperature difference.

43.Write the expression for rate of flow of heat if one end of a metallic rod is heated



$$H = K A \frac{T_C - T_D}{L}$$

The constant of proportionality K is called the thermal conductivity of the material.

44.Some cooking pots have copper coating on the bottom. Give reason.

Thermal conductivity of copper is high and it promotes the distribution of heat over the bottom of a pot for uniform cooking.

45.Why a brass tumbler feels much colder than a wooden tray on a chilly day?

Thermal conductivity of brass(metal) is greater than that of wood.

46.Houses made of concrete roofs get very hot during summer days.Why?

Thermal conductivity of concrete is moderately high.

47.What is convection?

Convection is a mode of heat transfer by actual motion of matter. It is possible only in fluids.

48.Give examples for natural convection

Sea breeze, Land breeze, Trade wind

49.Explain sea breeze.

Sea breeze is due to natural convection.

During the day, the ground heats up more quickly than large water bodies. This is due to greater specific heat capacity of water. The air in contact with the warm ground is heated . It expands, becomes less dense and rises . Then cold air above sea moves to fill this space and is called as sea breeze .

50.Explain land breeze

Land breeze is due to natural convection.

At night, the ground loses its heat more quickly, and the water surface is warmer than the land. The air in contact with water is heated. It expands, becomes less dense and rises . Then cold air above the ground moves to fill this space and is called as land breeze .

51.Give examples for forced convection.

Forced-air heating systems in home
The human circulatory system
The cooling system of an automobile engine.

52.What is radiation?

The mechanism for heat transfer which does not require a medium is called radiation.

53.Heat is transferred to the earth from the sun through empty space as …………………. Radiation.

54.We wear white or light coloured clothes in summer.Why?

White colour absorb the least heat from the sun.

55.During winter, we use dark coloured clothes .Why?

Dark colours absorb heat from the sun and keep our body warm.

56.The bottoms of the utensils for cooking food are blackened .Why?

Black colour absorbs maximum heat from the fire and give it to the vegetables to be cooked.

57.Explain the principle of thermo bottles.

It consists of a double-walled glass vessel with the inner and outer walls coated with silver. Radiation from the inner wall is reflected back into the contents of the bottle. The outer wall similarly reflects back any incoming radiation.

58.What is a black body?

An object that absorbs all radiations falling on it at all wavelength is called a blackbody. A blackbody, also emits radiations of all possible wavelength.

59.What are blackbody radiation?

The radiations emitted by blackbody are called blackbody radiations.

60.State Wien's displacement law.

The wavelength λ_m for which energy emitted by a blackbody is the maximum , is inversely roportional to the temperarure.This is known as Wien's Displacement Law.

$$\lambda_m \ \alpha \ \frac{1}{T}$$

$$\boldsymbol{\lambda_m\ T = \text{constant}}$$

The constant is called Wien's constant and its value is 2.9 x 10^{-3}mK.

61.State Stefan-Boltzmann law

The energy emitted by a radiator (black body) per unit time is given by

$$H = Ae\sigma T^4$$

where A - the area of the body, T - temperature of bod

E - the emissivity, σ = Stefan-Boltzmann constant =5.67 x10^{-8}W$m^{-2}$$K^{-4}$

62.State Newton's law of cooling

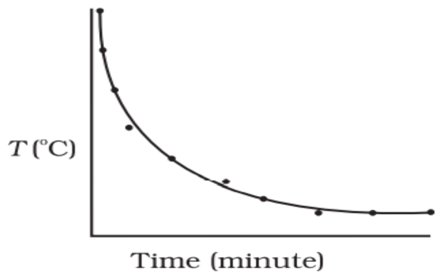
Newton's Law of Cooling says that the rate of loss of heat(rate of cooling) of a body is proportional the difference of temperature of the body and the surroundings. $$-\frac{dQ}{dt} = k(T_2 - T_1)$$

Where T_1 is the temperature of the surrounding medium

T_2 is the temperature of the body

k is a positive constant depending upon the area and nature of the surface of the body

63.Draw the curve showing cooling of hot water with time



Chapter 11
Thermodynamics

1.What do you mean by thermal equilibrium?

A system is said to be in thermal equilibrium with itself if the temperature of the system remains constant.

2.State Zeroth law of thermodynamics

Zeroth Law of Thermodynamics states that 'two systems in thermal equilibrium with a third system separately are in thermal equilibrium with each other'.

$$\text{i.e, If} \quad T_A = T_C \text{ and } T_B = T_C \quad \text{then} \quad T_A = T_B$$

3..State first law of Thermodynamics

The heat supplied to the system is partly used to increase the internal energy of the system and the rest is used to do work on the environment .

$$\Delta Q = \Delta U + \Delta W$$

4.First law of thermodynamics is in accordance with law of conservation of----------------------.

Energy

5.Derive the relation connecting C_p and C_v or Derve Mayer's relation

Molar specific heat capacity at constant volume,

$$C_v = \left(\frac{\Delta Q}{\Delta T}\right)_v$$

$$\Delta Q = \Delta U$$

$$C_v = \frac{\Delta U}{\Delta T} \text{---------}(1)$$

Molar specific heat capacity at constant pressure

$$C_p = \left(\frac{\Delta Q}{\Delta T}\right)_p$$

$$\Delta Q = \Delta U + P\,\Delta V$$

$$C_p = \left(\frac{\Delta U}{\Delta T}\right)_p + \left(P\frac{\Delta V}{\Delta T}\right)_p$$

$$C_p = \frac{\Delta U}{\Delta T} + \left(P\frac{\Delta V}{\Delta T}\right)_p \text{------------}(2)$$

$$PV = RT$$

$$P\left(\frac{\Delta V}{\Delta T}\right)_p = R$$

$$C_p = \frac{\Delta U}{\Delta T} + R$$

Substituting from eq(1) $\quad C_p = C_v + R$

$$\mathbf{C_p - C_v = R}$$

This is called Mayer's relation.

6. C_p is always greater than C_v . Why

When gas is heated at constant volume, the entire heat is used to increase the internal energy of the gas. But when the gas is heated at constant pressure, the heat is used to increase the internal energy and also to do external work during expansion. Hence C_p is greater than C_v.

7.What are thermodynamic state variables?

Every equilibrium state of a thermodynamic system is completely described by specific values of some macroscopic variables. These are called thermodynamic state variables.
Eg: pressure, volume, temperature, mass , composition,Entropy, Enthalpy

8.What do you mean by equation of state?

The connection between the state variables is called the equation of state.

9.Write the e quation of statefor an ideal gas

$$P V = \mu R T$$

10.What are extensive variables?

The thermodynamic variables which indicate the 'size' of the system are called extensive variables. Eg:Internal energy, Volume , Mass

11.What are intensive variables?

The thermodynamic variables which do not indicate the 'size' of the system are called intensive variables. Eg: Pressure, Temperature , Density

12.What is a quasi-static process?

The name quasi-static means nearly static.
A quasi-static process is an infinitely slow process such that the system remains in thermal and mechanical equilibrium with the surroundings throughout.

Eg: Processes that are sufficiently slow and do not involve accelerated motion of the piston, large temperature gradient, etc.

13.Different thermodynamic processes

Type of processes	Feature	
Isothermal	Temperature constant	$\Delta Q = \Delta W$ $(\Delta U = 0)$
Isobaric	Pressure constant	$\Delta Q = \Delta U + \Delta W$
Isochoric	Volume constant	$\Delta Q = \Delta U$ $(\Delta V = 0)$
Adiabatic	No heat flow between the system and the surroundings ($\Delta Q = 0$)	$\Delta Q = 0$ $\Delta W = -\Delta U$

14.Write the equation of state for an isothermal process.

$$PV = \text{constant}$$

15.Write the equation of state for an adiabatic process.

$$PV^{\gamma} = \text{constant}$$

16.Derive the expression for work done by an ideal gas during an isothermal process.

$$W = \int_{V_1}^{V_2} P\, dV$$

$$PV = \mu R T$$

$$P = \frac{\mu R T}{V}$$

$$W = \int_{V_1}^{V_2} \frac{\mu R T}{V}\, dV$$

$$W = \mu R T \int_{V_1}^{V_2} \frac{1}{V}\, dV$$

$$W = \mu R T\, [\ln V]_{V_1}^{V_2}$$

$$W = \mu R T\, [\ln V_2 - \ln V_1]$$

$$W = \mu R T \ln \left[\frac{V_2}{V_1}\right]$$

17.Derive the expression for workdone by an Ideal gas during an adiabatic process

$$W = \int_{V_1}^{V_2} P\, dV$$

$$PV^{\gamma} = k$$

$$P = \frac{k}{V^{\gamma}} = k\, V^{-\gamma}$$

$$W = k \int_{V_1}^{V_2} V^{-\gamma}\, dV$$

$$W = k \left[\frac{V^{-\gamma+1}}{-\gamma+1}\right]_{V_1}^{V_2}$$

$$W = \frac{k}{1-\gamma}\left[V_2^{\,1-\gamma} - V_1^{\,1-\gamma}\right]$$

$$W = \frac{1}{1-\gamma}\left[\frac{k}{V_2^{\,\gamma-1}} - \frac{k}{V_1^{\,\gamma-1}}\right]$$

$$PV^{\gamma} = k$$

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma} = k$$

$$W = \frac{1}{1-\gamma}\left[\frac{P_2 V_2^{\gamma}}{V_2^{\,\gamma-1}} - \frac{P_1 V_1^{\gamma}}{V_1^{\,\gamma-1}}\right]$$

$$W = \frac{1}{1-\gamma}\left[P_2V_2 - P_1V_1\right] \quad \text{(or)} \quad W = \frac{\mu R}{1-\gamma}\left[T_2 - T_1\right]$$

18.Workdone in an isochoric process is ------------ Zero

19.Work done by the gas in an Isobaric process

$$\Delta W = P\, \Delta V$$

$$W = P\,(V_2 - V_1)$$

20.What is a cyclic process?

In a cyclic process, the system returns to its initial state.

Since internal energy is a state variable, $\Delta U = 0$ for a cyclic process

21.State Kelvin-Planck statement of second law of thermodynamics

No process is possible whose sole result is the absorption of heat from a reservoir and the complete conversion of the heat into work.

22.State Clausius statement of second law of thermodynamics

No process is possible whose sole result is the transfer of heat from a colder object to a hotter object.

23.What is a reversible processes?

A thermodynamic process is reversible if the process can be turned back such that both the system and the surroundings return to their original states, with no other change anywhere else in the universe.

Eg: A quasi-static isothermal expansion of an ideal gas in a cylinder fitted with a frictionless movable piston is a reversible process.

24.What is an irreversible processes?

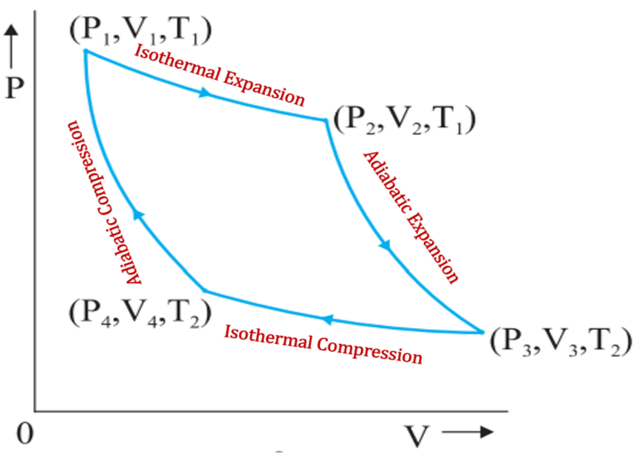
A thermodynamic process is irreversible if the process cannot be turned back such that both the system and the surroundings return to their original states, with no other change anywhere else in the universe.
The spontaneous processes of nature are irreversible.

- Eg:The free expansion of a gas
- The combustion reaction of a mixture of petrol and air ignited by a spark .
- Cooking gas leaking from a gas cylinder in the kitchen diffuses to the entire room. The diffusion process will not spontaneously reverse and bring the gas back to the cylinder.

25.What is the working substance of the Carnot engine.

Ideal gas.

26.Draw P-V diagram for a Carnot cycle .Also write different thermodynamic processes involved in a Carnot cycle.



The four processes involved in carnot cycle are

1.Isothermal Expansion
2. Adiabatic Expansion
3. Isothermal Compression
4. Adiabatic Compression

27.Write the expression for efficiency of Carnot engine

$$\eta = \frac{T_1 - T_2}{T_1} \quad \text{or} \quad \eta = 1 - \frac{T_2}{T_1}$$

28.Obtain the expression for in a Carnot cycle

(a)Step1→2 Isothermal expansion of the gas from (P_1, V_1, T_1) to (P_2, V_2, T_1).

$$W_{1\to2} = Q_1 = \mu RT_1 \ln\left|\frac{V_2}{V_1}\right| \text{------------}(1)$$

(b) Step 2→ 3 Adiabatic expansion of the gas from (P_2,V_2,T_1) to (P_3, V_3, T_2).

$$W_{2\to3} = \frac{\mu R}{\gamma-1}[T_1 - T_2] \text{------------------}(2)$$

(c)Step 3→4 Isothermal compression of the gas from(P_3,V_3,T_2) to (P_4,V_4,T_2).

$$W_{3\to4} = Q_2 = -\mu RT_2 \ln\left|\frac{V_3}{V_4}\right| \text{-----------}(3)$$

(d) Step 4 → 1 Adiabatic compression of the gas from (P_4,V_4,T_2) to (P_1,V_1, T_1)

$$W_{4\to1} = -\frac{\mu R}{\gamma-1}[T_1 - T_2] \text{-----------------}(4)$$

Total work done by the gas in one complete cycle is

$$W = W_{1\to2} + W_{2\to3} + W_{3\to4} + W_{4\to1}$$

$$W = \mu RT_1 \ln\left|\frac{V_2}{V_1}\right| + \frac{\mu R}{\gamma-1}[T_1 - T_2] - \mu RT_2 \ln\left|\frac{V_3}{V_4}\right| - \frac{\mu R}{\gamma-1}[T_1 - T_2]$$

$$W = \mu RT_1 \ln\left|\frac{V_2}{V_1}\right| - \mu RT_2 \ln\left|\frac{V_3}{V_4}\right| \text{-------------}(5)$$

Efficiency, $\eta = 1 - \frac{Q_2}{Q_1}$

$$\eta = 1 - \frac{\mu RT_2 \ln\left|\frac{V_3}{V_4}\right|}{\mu RT_1 \ln\left|\frac{V_2}{V_1}\right|}$$

but $\frac{V_3}{V_4} = \frac{V_2}{V_1}$

$$\eta = 1 - \frac{T_2}{T_1}$$

29.What is the efficiency of a Carnot engine working between 233K and 373K.

Or

What is the efficiency of a heat engine working between ice point 0^0C and steam point 100^0C .

$$\eta = \frac{T_1 - T_2}{T_1}$$

$T_1 = 100 + 273 = 373^0C$

$T_2 = 0 + 273 = 273^0C$

$$\eta = \frac{373 - 273}{373}$$

$\eta = 0.268 = 26.8\%$

Chapter 12
Kinetic Theory

1.Real gases approach ideal gas behaviour at ....

Low pressures and high temperatures.

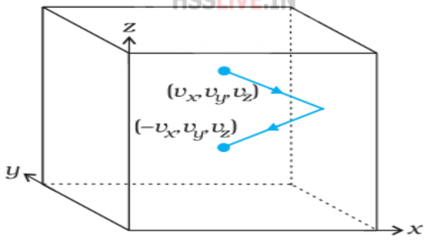
2.State Dalton's law of partial pressures

The total pressure of a mixture of ideal gases is the sum of partial pressures. This is Dalton's law of partial pressures.

3.Write any four postulates of kinetic theory of an Ideal Gas

- A given amount of gas is a collection of a large number of molecules that are in random motion.
- At ordinary pressure and temperature, the average distance between molecules is very large compared to the size of a molecule (2 Å).
- The interaction between the molecules is negligible.
- The molecules make elastic collisions with each other and also with the walls of the container .
- As the collisions are elastic , total kinetic energy and total momentum are conserved .
- The average kinetic energy of a molecule is proportional to the absolute temperature of the gas.

4.Derive the expression for pressure of an ideal gas



The change in momentum of the molecule $= -mv_x - mv_x$

$= -2\ mv_x$

Momentum imparted to wall in the collision $= 2mv_x$

Distance travelled by the molecule in time $\Delta t = v_x\ \Delta t$

Volume covered by the molecule $= Av_x\ \Delta t$

No of molecules in this volume $= n\ Av_x\ \Delta t$

(n is number density of molecules)

Only half of these molecules move in +x direction

So no of molecules $= \frac{1}{2}\,nA\ v_x\ \Delta t$

The number of molecules with velocity v_x hitting the wall in time Δt

$$= \frac{1}{2}\,nA\ v_x\ \Delta t$$

The total momentum transferred to the wall

$$Q = (2mv_x)\left(\frac{1}{2}\,nA\ v_x\ \Delta t\right)$$

$$Q = nmAv_x^{\,2}\ \Delta t$$

The force on the wall, $F = \frac{Q}{\Delta t}$

$$F = nmAv_x{}^2$$

Pressure, $P = \frac{F}{A}$

$$P = nmv_x{}^2$$

All molecules in a gas do not have the same velocity; so average velocity is to be taken

$$P = nm\overline{v_x^2}$$

$$\overline{v_x^2} = \frac{1}{3}\overline{v^2}$$

$$P = \frac{1}{3}nm\overline{v^2}$$

5.Show that the average kinetic energy of a molecule is proportional to the absolute temperature of the gas.

$$P = \frac{1}{3}nm\overline{v^2}$$

$$n = \frac{N}{V}, \quad N = nV$$

$$PV = \frac{1}{3}Nm\overline{v^2}$$

where N is the number of molecules in the sample.

$$PV = \frac{2}{3}\left(N\ \frac{1}{2}m\overline{v^2}\right)$$

$$PV = \frac{2}{3}E \text{------------------(1)}$$

Ideal gas equation, $PV = Nk_BT$ ------------------(2)

From eq(1)and (2) $\frac{2}{3}E = Nk_BT$

$$E = \frac{3}{2}Nk_BT$$

$$E/N = \frac{3}{2}k_BT$$

The average kinetic energy of a molecule is proportional to the absolute temperature

6.Obtain the expression for Root Mean Square (rms) Speed of a molecule of an ideal gas

$$E/N = \frac{3}{2}k_BT$$

$$\frac{1}{2}m\overline{v^2} = \frac{3}{2}k_BT$$

$$\overline{v^2} = \frac{3k_B T}{m}$$

$$\mathbf{v_{rms}} = \sqrt{\frac{\mathbf{3k_B T}}{\mathbf{m}}}$$

7.Estimate the average thermal energy of helium atom at a temperature of 27^0C. (Boltzmann constant is 1.38 x 10^{-23}JK)

Average thermal energy(average kinetic energy) $= \frac{3}{2} k_B T$

(T=27+273=300K)

$$\text{Average thermal energy} = \frac{3}{2} \text{ x } 1.38 \text{ x } 10^{-23} \text{ x } 300$$
$$= 6.21 \text{ x } 10^{-21} \text{J}$$

8.Define degrees of freedom of a gas molecule?

The total number of independent ways in which a system can possess energy is called degree of freedom.

A molecule has one degree of freedom for motion in a line.

Two degrees of freedom for motion in a plane.

Three degrees of freedom for motion in space.

9.State law of equipartition of energy

Law of Equipartition of Energy states that, in equilibrium, the total energy is equally distributed in all possible energy modes, with each mode having an average energy equal to $\frac{1}{2} \mathbf{k_B T}$

10.By using law of equipartiotion of energy obtain the values of specific heat capacities of monoatomic gases. Also find the value of γ

The molecule of a monatomic gas has only 3 translational degrees of freedom.

Average energy of one molecule $= 3 \; x \; \frac{1}{2} k_B T = \frac{3}{2} k_B T$

The total internal energy of one mole ,

$$U = \frac{3}{2} k_B T \text{ x } N_A$$

$$k_B N_A = R$$

$$U = \frac{3}{2} RT$$

$$C_v = \frac{dU}{dt}$$
$$= \frac{d}{dT}\left(\frac{3}{2} RT\right)$$
$$\mathbf{C_V = \frac{3}{2} R}$$

Mayer's relation, $C_P - C_V = R$

$$C_P = C_V + R$$
$$= \frac{3}{2} R + R$$
$$\mathbf{C_P = \frac{5}{2} R}$$

The ratio of specific heats

$$\frac{C_P}{C_P} = \gamma = \frac{\frac{5}{2}R}{\frac{3}{2}R}$$

Adiabatic constant , $\boldsymbol{\gamma = \frac{5}{3}}$

11.By using law of equipartition of energy obtain the values of specific heat capacities of rigid diatomic molecule. Also find the value of γ

A diatomic rigid rotator has , 3 translational and 2 rotational degrees of freedom.

$$\text{Average energy of one molecule} = 5 \ x \frac{1}{2} k_B T$$
$$= \frac{5}{2} k_B \ T$$

The total internal energy of one mole,

$$U = \frac{5}{2} k_B \ T \ x \ N_A$$
$$k_B N_A = R$$
$$U = \frac{5}{2} RT$$
$$C_V = \frac{dU}{dt}$$
$$= \frac{d}{dT}\left(\frac{5}{2} RT\right)$$
$$\boldsymbol{C_V = \frac{5}{2} R}$$

$$\text{Mayer's relation, } C_P - C_V = R$$
$$C_P = C_V + R$$
$$= \frac{5}{2} R + R$$
$$\boldsymbol{C_P = \frac{7}{2} R}$$

The ratio of specific heats

$$\frac{C_P}{C_P} = \gamma = \frac{\frac{7}{2}R}{\frac{5}{2}R}$$

Adiabatic constant , $\boldsymbol{\gamma = \frac{7}{5}}$

12.By using law of equipartition of energy obtain the values of specific heat capacities of non rigid diatomic molecule. Also find the value of γ

A non rigid diatomic molecule has , 3 translational , 2 rotational and 1 vibrational degrees of freedom.

(Each vibrational degree of freedom contributes ,2x $\frac{1}{2}k_BT = k_BT$)

Average energy of one molecule $= \frac{5}{2}k_BT + k_B T$

$$= \frac{7}{2}k_BT$$

The total internal energy of one mole ,

$$U = \frac{7}{2}k_B T \times N_A$$

$$k_BN_A = R$$

$$U = \frac{7}{2}RT$$

Specific heat capacity at constant volume

$$C_V = \frac{dU}{dt}$$

$$= \frac{d}{dT}\left(\frac{7}{2}RT\right)$$

$$\mathbf{C_V = \frac{7}{2}R}$$

Mayer's relation, $C_P - C_V = R$

$$C_P = C_V + R$$

$$= \frac{7}{2}R + R$$

$$\mathbf{C_P = \frac{9}{2}R}$$

The ratio of specific heats

$$\frac{C_P}{C_P} = \gamma = \frac{\frac{9}{2}R}{\frac{7}{2}R}$$

Adiabatic constant , $\boldsymbol{\gamma = \frac{9}{7}}$

13.By using law of equipartition of energy obtain the values of specific heat capacities of Polyatomic Gases. Also find the value of γ

A polyatomic molecule has 3 translational, 3 rotational degrees of freedom and a certain number (f) of vibrational modes.

Average energy of a molecule $= \frac{3}{2}k_BT + \frac{3}{2}k_BT + f\,k_BT$

The total internal energy of a mole of such a gas is,

$$U = \left(\frac{3}{2}k_BT + \frac{3}{2}k_BT + f\,k_BT\right)N_A$$

$$U = (3 + f)k_BTN_A$$

$$(k_BN_A = R)$$

$$U = (3 + f)RT$$

Specific heat capacity at constant volume

$$C_V = \frac{dU}{dt}$$

$$\mathbf{C_V = (3 + f)R}$$

Specific heat capacity at constant pressure,

$$C_P = C_V + R$$
$$= (3 + f)R + R$$
$$\mathbf{C_P = (4 + f)R}$$

The ratio of specific heats

$$\gamma = \frac{C_P}{C_P} = \frac{(4+f)R}{(3+f)R}$$

Adiabatic constant , $\boldsymbol{\gamma = \frac{(4+f)}{(3+f)}}$

14.By using law of equipartition of energy obtain the values of specific heat capacity of of solids

Consider a solid of N atoms, each vibrating about its mean position.

A vibration in one dimension has average energy $= 2x\ \frac{1}{2}k_BT$

$$= k_BT$$

In three dimensions, the average energy $= 3k_BT$

The total internal energy of one mole of solid is,

$$U = 3k_BT \text{ x } N_A$$

$$k_BN_A = R$$

$$U = 3RT$$

Specific heat capacity $C = \frac{dU}{dt}$

$$= \frac{d}{dT}(3\ RT)$$

$$\mathbf{C = 3R}$$

15.Define mean free path of a gas molecule.

The mean free path l is the average distance covered by a molecule between two successive collisions.

$$\boldsymbol{l = \frac{1}{\sqrt{2}n\pi d^2}}$$

Chapter 13
Oscillations

1.What is non periodic motion?

The motion which is non-repetitive .

e.g. rectilinear motion , motion of a projectile.

2.What is periodic motion?

A motion that repeats itself at regular intervals of time is called periodic motion.

e.g. uniform circular motion , orbital motion of planets in solar system.

3.What is oscillatory motion?

Periodic to and fro motion is called oscillatory motion.

e.g. motion of a cradle , motion of a swing, motion of the pendulum of a wall clock.

Every oscillatory motion is periodic, but every periodic motion need not be oscillatory.

4.What is the difference between oscillations and vibration?

- When the frequency is small, we call it oscillation.
  e.g.The oscillation of a branch of a tree
- When the frequency is high, we call it vibration.
  e.g. The vibration of a string of a musical instrument.

5.What is period of oscillation?

The period T is the time required for one complete oscillation, or cycle.

Its SI unit is second.

6.What is frequency of oscillation?

The frequency ν of periodic or oscillatory motion is the number of oscillations per unit time. It is the reciprocal of period .

$$\nu = \frac{1}{T}$$ The SI unit of ν is hertz (Hz).

7.Define amplitude of oscillation.

The maximum displacement from the mean poition is called amplitude (A) of oscillation

8.Define Simple Harmonic Motion(SHM)

Simple harmonic motion is the motion executed by a particle subject to a force, which is proportional to the displacement of the particle and is directed towards the mean position.

9.Write a mathematical expression for an SHM. Explain the terms.

$$x(t) = A\cos(\omega t + \phi)$$

$x(t)$ =displacement, A=amplitude , ω =angular frequency,
$(\omega t + \phi)$ = phase , ϕ=phase constant or initial phase angle

10.Write the expression for angular frequency

$$\omega = \frac{2\pi}{T} \quad \text{or} \quad \omega = 2\pi\nu$$

Unit of ω is rad/s

Angular frequency is a scalar quantity

11.An SHM is given by $x = 8\sin(10\pi t + \frac{\pi}{4})$ m

Find the (i) aplitude (ii)Angular frequency (iii)period (iv)frequency(v) initial phase angle or phase constant

$$x = 8\sin(10\pi t + \frac{\pi}{4})$$

Comparing with general expression for SHM

$$x(t) = A\cos(\omega t + \phi)$$

(i)Amplitude , A=8 m

(ii)Angular frequency , $\omega = 10\pi$ rad/s

(iii)$\omega = \frac{2\pi}{T}$

Period , $T = \frac{2\pi}{\omega} = \frac{2\pi}{10\pi} = 1/5$ s

(iv)Frequency , $\nu = \frac{1}{T} = \frac{5}{1} = 5$Hz

(v)Initial phase angle, $\phi = \frac{\pi}{4}$ rad

12.Write the expression for velocity in Simple Harmonic Motion.

$$v = -\omega A\sin(\omega t + \phi)$$

13.Write the expression for acceleration in SHM

$$\mathbf{a = -\omega^2 x}$$

In SHM, the acceleration is proportional to the displacement and is always directed towards the mean position.

14.Obtain the expression for force for Simple Harmonic Motion

$$F = ma$$

$$a = -\omega^2 x$$

$$F = -m\omega^2 x$$

$$F = -kx \text{ -------------}(4)$$

where $k = m\omega^2$; $\omega = \sqrt{\frac{k}{m}}$

The force in SHM is proportional to the displacement and its direction is opposite to the direction of displacement. Therefore, it is a restoring force.

15.Derive the expression for kinetic energy in Simple Harmonic Motion

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

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

$$v = -\omega\sqrt{A^2 - x^2}$$

$$v^2 = \omega^2 (A^2 - x^2)$$

$$K = \frac{1}{2} m\omega^2 (A^2 - x^2) \text{ ----------------(5)}$$

- At mean position,(x= 0), $K = \frac{1}{2} m\omega^2 A^2$

  KE is maximum At Mean position
- At extreme position,(x= A), K= 0.

  KE is minimum At extreme positions.

16.Obtain the expression for potential energy in simple harmonic motion

$$U = \frac{1}{2} kx^2$$

$$k = m\,\omega^2$$

$$U = \frac{1}{2} m\omega^2 x^2 \text{ ----------------(6)}$$

- At Mean position, x= 0 , $U = 0$

  PE is minimum At Mean position
- At Extreme position, x = A , $U = \frac{1}{2} m\omega^2 A^2$

  PE is maximum At extreme positions.

17.Derive the expression for total energy in SHM

$$E = U + K$$

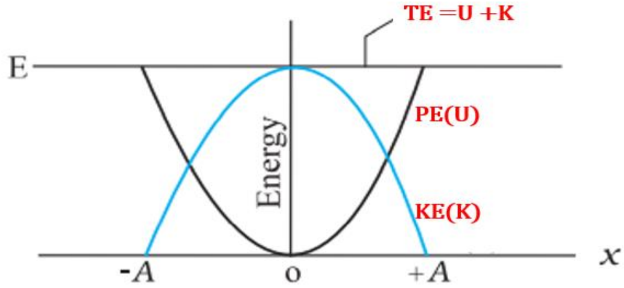
$$E = \frac{1}{2} m\omega^2 x^2 + \frac{1}{2} m\omega^2 (A^2 - x^2)$$

$$E = \frac{1}{2} m\omega^2 x^2 + \frac{1}{2} m\omega^2 A^2 - \frac{1}{2} m\omega^2 x^2$$

$$\mathbf{E = \frac{1}{2} m\omega^2 A^2}$$

The total mechanical energy of a harmonic oscillator is a constant or independent of time.

18.Draw the variation of potential energy , kinetic energy k and the total energy e with time t for a linear harmonic oscillator



19.At what position the KE of a simple harmonic oscillator becomes equal to its potential energy?

$$KE = PE$$

$$\frac{1}{2}m\omega^2(A^2 - x^2) = \frac{1}{2}m\omega^2x^2$$

$$A^2 - x^2 = x^2$$

$$A^2 = 2x^2$$

$$x^2 = \frac{A^2}{2}$$

$$\mathbf{x = \frac{A}{\sqrt{2}}}$$

20.Give examples of systems executing simple harmonic motion

- Oscillations due to a Spring
- Oscillations of a simple pendulum

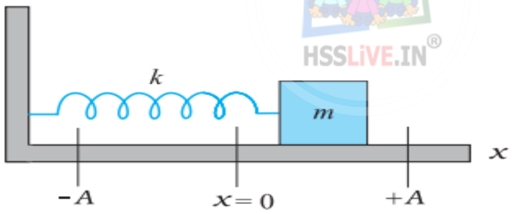
21.Define spring constant of a spring.

The restoring force per unit displacement of the spring is called spring constant.

$$k = \frac{F}{x} = \frac{mg}{x}$$

A stiff spring has large k and a soft spring has small k.

22.Derive the expression for period of oscillations of a spring



Restoring force, $F = -kx$

where $k = m\omega^2$

$$\omega^2 = \frac{k}{m}, \quad \omega = \sqrt{\frac{k}{m}}$$

Period, $T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{k}{m}}}$

$$\mathbf{T = 2\pi\sqrt{\frac{m}{k}}}$$

23.A 5 kg collar is attached to a spring of spring constant 500 N m^{-1}. It slides without friction over a horizontal rod. The collar is displaced from its equilibrium position by 10.0 cm and released. Calculate

(a) the period of oscillation,

(b) the maximum speed and

(c) maximum acceleration of the collar.

(a) The period of oscillation as given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{5}{500}}$$

$$T = 2x\ 3.14\ x\frac{1}{10} = 0.63\ s$$

(b) The velocity of the collar executing SHM is

$$v = -\,\omega\sqrt{A^2 - x^2}$$

Maximum speed, $v= A\omega$ (at mean position ,x=0)

$$\omega = \sqrt{\frac{k}{m}}$$

$$v = A\sqrt{\frac{k}{m}}$$

$$A=10cm = 0.1m$$

$$v = 0.1\ x\sqrt{\frac{500}{5}}$$

$$v= 0.1\ x10 =1\ m/s$$

(c) Acceleration in SHM

$$a=-\,\omega^2 x$$

Maximum acceleration, $a=\omega^2 A$ (at extreme position)

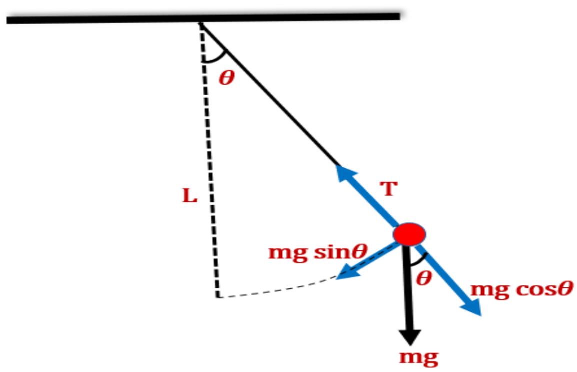
$$\omega^2 = \frac{k}{m}$$

$$a= \frac{k}{m}A$$

$$a= \frac{500}{5}x\ 0.1$$

$$a=10m/s^2$$

24.Derive the expression for period of oscillations of a simple pendulum



$$\tau = -L\ (mg\ \sin\theta\ ) \text{ --------------(1)}$$

For rotational motion we have,

$$\tau = I\ \alpha \text{ -----------------(2)}$$

From eqn (1) and (2)

$$I\alpha = -L\,mg\sin\theta$$

$$\alpha = \frac{-mgL}{I}\theta \text{ ---------------(3)} \qquad \text{(since } \theta \text{ is very small, } \sin\theta \approx \theta)$$

Acceleration of SHM , $a = -\omega^2 x$ ------------------(4)

Comparing eqns (3) and (4)

$$\omega^2 = \frac{mgL}{I}$$

$$I = mL^2$$

$$\omega^2 = \frac{mgL}{mL^2} = \frac{g}{L}$$

$$\omega = \sqrt{\frac{g}{L}}$$

Period, $T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{g}{L}}}$

$$\mathbf{T = 2\pi\sqrt{\frac{L}{g}}}$$

25.A girlis swinging on a swing in sitting position with period T. What will happen to the period of oscillation when she stands up?

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

When she stands up ,the length of the pendulum decreases and hence period of oscillation decreases.

26.What is a seconds pendulum?

A simple pendulum of period T = 2 second is called a seconds pendulum.

27.What is the length of a simple pendulum, which ticks seconds? Or What is the length of a seconds pendulum ?

A simple pendulum of period T = 2 second is called a seconds pendulum.

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

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

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

For seconds pendulum ,T = 2s

$$L = \frac{2^2 \times 9.8}{4 \times 3.14^2} = 0.994 \approx 1\text{m}$$

Chapter 14
Waves

1.The waves governed by Newton's laws, and require a material medium for their propagation are called ……………………..

Mechanical waves

E.g, water waves, sound waves, seismic waves, etc.

2.The waves which not require any medium for their propagation and travel through vacuum at speed of light are …………………

Electromagnetic waves

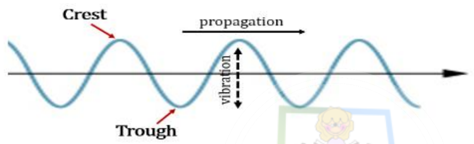
Eg- visible light, ultraviolet light, radio waves, microwaves, x-rays etc.

3.The waves associated with moving electrons, protons, neutrons and other fundamental particles are called…………..

Matter waves.

4.Write the characteristics of transverse waves

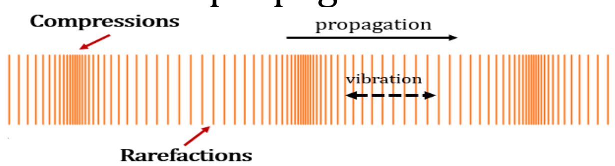
- In transverse waves, the constituents of the medium oscillate perpendicular to the direction of wave propagation.



- They travel in the form of crests and troughs.
- Transverse waves can be propagated only in solids and strings, and not in fluids.
- E.g, Waves on a stretched string,

5.Write the characteristics of longitudinal waves

- In longitudinal waves the constituents of the medium oscillate along the direction of wave propagation.



- They travel in the form of compressions and rarefactions.
- Longitudinal waves can propagate in all elastic media,i.e,solids,liquids nd gases.
- E.g, sound waves, vibrations in a spring.

6.Given below are some examples of wave motion. State in each case if the wave motion is transverse, longitudinal or a combination of both:

(a)Motion of a kink(particle) in a longitudinal spring produced by displacing one end of the spring sideways.

(b)Waves produced in a cylinder containing a liquid by moving its piston back and forth.

(c) Waves produced by a motorboat sailing in water.

(d) Ultrasonic waves in air produced by a vibrating quartz crystal.

(e) The waves in an ocean.

Answer:- (a) Transverse and longitudinal
(b) Longitudinal
(c) Transverse and longitudinal
(d) Longitudinal
(e) Transverse and longitudinal

7.What is a travelling wave or progressive wave?

A wave, transverse or longitudinal, is said to be travelling or progressive if it travels from one point of the medium to another.

8.Write the displacement relation for a progressive wave travelling along the positive direction of the x-axis and explain the terms.

$$y(x, t) = a \sin(kx - \omega t + \phi)$$

$y(x, t)$ = displacement
a=amplitude
$(kx - \omega t + \phi)$ =phase,
k=wave number or propagation constant
ω=angular frequency
Φ =initial phase angle or phase constant

9.Write the displacement relation for a progressive wave travelling along the negative direction of the x-axis

$$y(x, t) = a \sin(kx + \omega t + \phi)$$

10.Write the equation for propagation constant or angular wave number

$$k = \frac{2\pi}{\lambda}$$

Its SI unit is radian per metre or rad m^{-1}

11.Write the equation for angular frequency

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

Its SI unit is rad s^{-1}

12.A wave travelling along a string is described by, $y(x, t) = 0.005 \sin(80.0x - 3.0t)$, in which the numerical constants are in SI units (0.005 m, 80.0 rad m^{-1}, and 3.0 rad s^{-1}). Calculate

(a) the amplitude,
(b) the wavelength,
(c) the period and frequency of the wave.
(d) Calculate the displacement y of the wave at a distance x = 30.0 cm and time t = 20 s ?

Answer

$$y(x, t) = 0.005 \sin (80.0\, x - 3.0\, t)$$

The general expression for a travelling wave is

$$y(x,t) = a \sin (kx - \omega t + \phi)$$

Comparing these equations

(a) Amplitude , a=0.005m

(b) k=80 rad m^{-1}

but , k= $\frac{2\pi}{\lambda}$

$$\frac{2\pi}{\lambda} = 80$$

$$\lambda = \frac{2\pi}{80} = 0.0785 \text{ m}$$

$$\lambda = 7.85\ cm$$

(c) ω=3

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

$$\frac{2\pi}{T} = 3$$

$$T = \frac{2\pi}{3} = 2.09 \text{ s}$$

Frequency, $\nu = 1/T$

$= 1/2.09 = 0.48$ Hz

(d) $y(x, t) = 0.005 \sin (80.0\, x - 3.0\, t)$

x = 30.0 cm =0.3m

t = 20 s

$y(x, t) = 0.005 \sin (80.0 \times 0.3 - 3.0 \times 20)$

$= (0.005 \text{ m}) \sin (-36)$

$= 5$ mm

12.Derive the expression for speed of a travelling wave

Consider a wave propagating in positive x direction with initial phase ϕ =0

$$y(x, t) = a \sin (kx - \omega t)$$

Here, $(kx - \omega t) = \text{constant}$

$$\frac{d}{dt}(kx - \omega t\ ) = 0$$

$$k\frac{dx}{dt} - \omega\frac{dt}{dt} = 0$$

$$\frac{dx}{dt} = \frac{\omega}{k}$$

$$\mathbf{v = \frac{\omega}{k}}$$

$$v = \frac{2\pi\nu}{\frac{2\pi}{\lambda}}$$

$$\mathbf{v = \nu\lambda}$$

13.Write the expression for speed of a transverse wave on stretched string

$$v=\sqrt{\frac{T}{\mu}}$$

μ - linear mass density or mass per unit length, $\mu=\frac{m}{l}$

T-Tension on the string.

14.A steel wire 0.72 m long has a mass of 5.0×10^{-3}kg. If the wire is under a tension of 60 N. What is the speed of transverse waves on the wire ?

$$v=\sqrt{\frac{T}{\mu}}$$

$$\mu = \frac{M}{l} = \frac{5.0 \times 10^{-3}}{0.72} = 6.9 \times 10^{-3}\ \text{kg}\ m^{-1}$$

$$T = 60\ N$$

$$v=\sqrt{\frac{60}{6.9 \times 10^{-3}}}$$

$$v= 93\ m\ s^{-1}$$

15.Asteel wire has a length of 12m and a mass of 2.1 kg. What is the tension in the wire if the speed of transverse wave on the on the wire is 343ms^{-1}

$$v=\sqrt{\frac{T}{\mu}}$$

$$v^2 = \frac{T}{\mu}$$

$$T= v^2\ \mu$$

$$T= v^2 \times \frac{M}{l}$$

$$T\ = 343^2 \times \frac{2.1}{12} = 20588.56\ N = 2.06\ 10^4 N$$

16.Write the expression for speed of a transverse wave on stretched string.

$$v=\sqrt{\frac{T}{\mu}}$$

μ = linear mass density or mass per unit length=$\frac{m}{l}$

T=tension on string

17.Write the expression for speed of longitudinal wave in a fluid

$$v=\sqrt{\frac{B}{\rho}}$$

B= the bulk modulus of medium

ρ = the density of the medium

18.Write the expression for speed of a longitudinal wave in a solid bar

$$v=\sqrt{\frac{Y}{\rho}}$$

Y =Young's modulus

ρ=density of the medium,

19.Write Newtons Formula for speed of a longitudinal wave in an ideal gas

$$v=\sqrt{\frac{P}{\rho}}$$

P= Pressure of gas

ρ = density of gas

20. Write Laplace correction to Newton's formula for speed of a longitudinal wave in an ideal gas

$$v=\sqrt{\frac{\gamma P}{\rho}}$$

P= Pressure of gas

ρ = density of gas

$\gamma = \frac{C_P}{C_V}$

21.Derive Newtons Formula for speed of a longitudinal wave in an ideal gas

$$v=\sqrt{\frac{B}{\rho}}$$

Newton assumed that, the pressure variations in a medium during propagation of sound are isothermal.

For isothermal process, PV = constant

$$V\Delta P + P\Delta V = 0$$

$$V\Delta P = -P\Delta V$$

$$\frac{-V\Delta P}{\Delta V} = P$$

$$B = P$$

$$v=\sqrt{\frac{P}{\rho}}$$

22.Derive Laplace correction to Newton's formula for speed of a longitudinal wave in an ideal gas.

$$v=\sqrt{\frac{B}{\rho}}$$

Laplace found that the pressure variations in a medium during propagation of sound are adiabatic and not isothermal.

For adiabatic process, PV^{γ} = constant

$$\Delta\, PV^{\gamma} = 0$$

$$P\gamma V^{\gamma-1}\Delta V + V^{\gamma}\,\Delta P = 0$$

$$P\,\gamma V^{\gamma-1}\Delta V = -\,V^{\gamma}\,\Delta P$$

$$\gamma\, P = \frac{-V^{\gamma}\Delta P}{V^{\gamma-1}\Delta V}$$

$$\gamma\, P = \frac{-V\Delta P}{\Delta V} = B$$

$$B = \gamma\, P$$

$$\mathbf{v=\sqrt{\frac{\gamma\, P}{\rho}}}$$

23.The speed of sound in air at STP = ---------------

331.3 m s^{-1}

24.A progressive gets reflected at a rigid boundary . Write the displacement relation for incident wave and reflected wave.

Incident wave, y_i(x, t) = a sin (kx – ωt)

Reflected wave, y_r(x, t) = a sin (kx + ωt + π)

- For reflection at a rigid boundary ,the reflected wave will have a phase reversal i.e, a phase difference of π radian or 180^0.
- For reflection at a rigid boundary ,the displacement at the boundary is zero

25.A progressive gets reflected at a open boundary . Write the displacement relation for incident wave and reflected wave.

Incident wave, y_i(x, t) = a sin (kx – ωt)

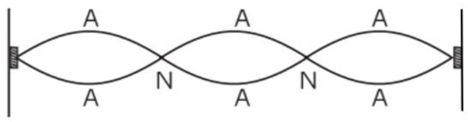
Reflected wave, y_r(x, t) = a sin (kx + ωt).

- The reflected wave will have same sign (no phase reversal) and amplitude as the incident wave.
- There will be maximum displacement at the boundary(twice the amplitude of either of the pulses)

26.What are standing waves?

The interference of two identical waves moving in opposite directions produces standing waves.

27.Draw standing waves in a stretched string and mark nodes and antinodes.



28.Obtain the expression for a standing wave and find the condition for nodes and antinodes.

Wave travelling in +ve x-axis, $y_1(x, t) = a \sin(kx - \omega t)$

Wave travelling in -ve x-axis , $y_2(x, t) = a \sin(kx + \omega t)$

When they superpose, $y(x, t) = y_1(x, t) + y_2(x, t)$

$y(x, t) = a \sin(kx - \omega t) + a \sin(kx + \omega t)$

$y(x, t) = (2a \sin kx) \cos \omega t$

Amplitude of wave , A= $2a \sin kx$.

Condition for Nodes

The positions of zero amplitude in a staning wave are called nodes.

$2a \sin kx = 0$

$\sin kx = 0$

$kx = n\pi$, for n = 0, 1, 2, 3, ..

But $k = \frac{2\pi}{\lambda}$

$\frac{2\pi}{\lambda} x = n\pi$

$x = n\frac{\lambda}{2}$, for n = 0, 1, 2, 3, ..

Condition for Antinodes

The positions of maximum amplitude are called antinodes.

$2a \sin kx = \text{maximum}$

$\sin kx = \pm 1$

$kx = (n + \frac{1}{2})\pi$, for n = 0, 1, 2, 3, ..

but ,$k = \frac{2\pi}{\lambda}$

$\frac{2\pi}{\lambda} x = (n + \frac{1}{2})\pi$

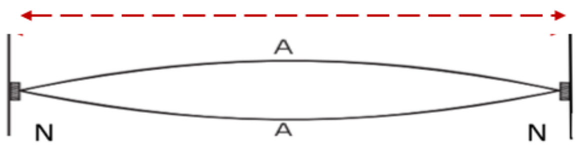
$x = (n + \frac{1}{2})\frac{\lambda}{2}$, for n = 0, 1, 2, 3, ...

29.Draw the different modes of standing waves produced in a stretched string fixed at both the ends. Also obtain the frequencies of harmonics . (or) Prove that the frquencies produced in a stretched string fixed at both ends are in the ratio 1: 2: 3

Fundamental mode or the first harmonic

The oscillation mode with n=1 , the lowest frequency is called the fundamental mode or the first harmonic.

$L = \frac{\lambda_1}{2}$



$$L = \frac{\lambda_1}{2}$$

$$\lambda_1 = 2L$$

But $v=\nu\lambda$

$$\nu = \frac{v}{\lambda}$$

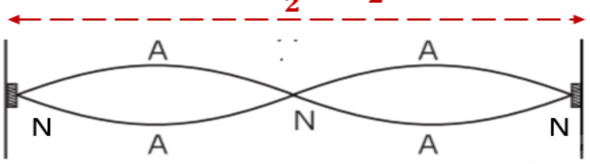
$$\text{Frequency, } \nu_1 = \frac{v}{\lambda_1}$$

$$\nu_1 = \frac{v}{2L} \text{ ----------(1)}$$

The second harmonic

The second harmonic is the oscillation mode with n = 2.

$L = 2\frac{\lambda_2}{2} = \lambda_2$



$$L = 2\frac{\lambda_2}{2} = \lambda_2$$

$$\lambda_2 = L$$

$$\text{Frequency, } \nu_2 = \frac{v}{\lambda_2}$$

$$\nu_2 = \frac{v}{L}$$

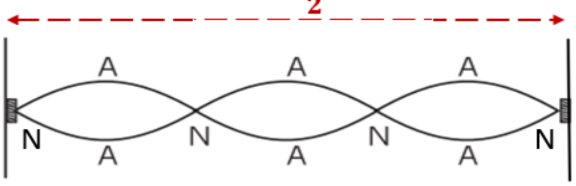
$$\nu_2 = 2\frac{v}{2L} \text{ -------------(2)}$$

$$\nu_2 = 2\nu_1$$

The Third Harmonic

The third harmonic is the oscillation mode with n = 3.

$L = 3\frac{\lambda_3}{2}$



$$L = 3\frac{\lambda_3}{2}$$

$$\lambda_3 = \frac{2L}{3}$$

$$\text{Frequency, } \nu_3 = \frac{v}{\lambda_3}$$

$$\nu_3 = \frac{v}{\frac{2L}{3}}$$

$$\nu_3 = 3\frac{v}{2L} \text{ --------------(3)}$$

$$\nu_3 = 3\nu_1$$

and so on

$$\nu_1 : \nu_2 : \nu_3 = 1 : 2 : 3$$

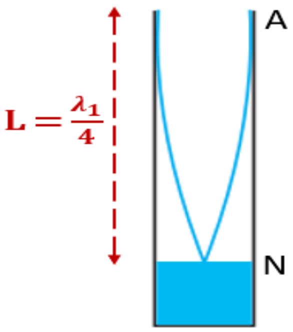
Thus all harmonics are possible in a stretched string fixed at both the ends.

30.Draw the different modes of standing waves produced in a closed pipe. Also obtain the frequencies of harmonics .
(or) Prove that the frquencies produced in a closed pipe are in the ratio 1: 3: 5 (or) Show that only odd harmonics are possible in a closed pipe.

Eg: Resonance Column(Air columns such as glass tubes partially filled with water) .

Fundamental mode or the first harmonic

The oscillation mode with n=0 , fundamental mode or the first harmonic.



$$L = \frac{\lambda_1}{4}$$

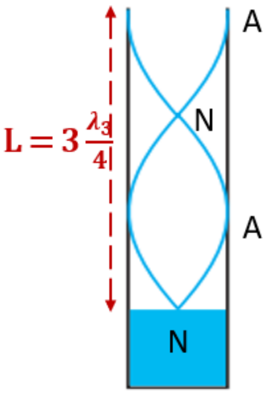
$$\lambda_1 = 4L$$

$$\text{Frequency, } \nu_1 = \frac{v}{\lambda_1}$$

$$\nu_1 = \frac{v}{4L} \text{------------}(1)$$

The Third Harmonic

The Third harmonic is the oscillation modewith n=1



$$L = 3\frac{\lambda_3}{4}$$

$$\lambda_3 = \frac{4L}{3}$$

$$\text{Frequency, } \nu_3 = \frac{v}{\lambda_3}$$

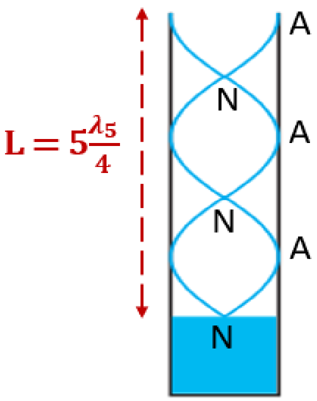
$$\nu_3 = \frac{v}{\frac{4L}{3}}$$

$$\nu_3 = 3\frac{v}{4L} \text{--------------}(2)$$

$$\nu_3 = 3\nu_1$$

The Fifth Harmonic

The Fifth harmonic is the oscillation mode with n = 2



$$L = 5\frac{\lambda_4}{4}$$

$$\lambda_4 = \frac{4L}{5}$$

$$\text{Frequency, } \nu_5 = \frac{v}{\lambda_5}$$

$$\nu_5 = \frac{v}{\frac{4L}{5}}$$

$$\nu_5 = 5\frac{v}{4L} \text{-------------}(3)$$

$$\nu_5 = 5\nu_1$$

$$\nu_1 : \nu_3 : \nu_5 = 1 : 3 : 5$$

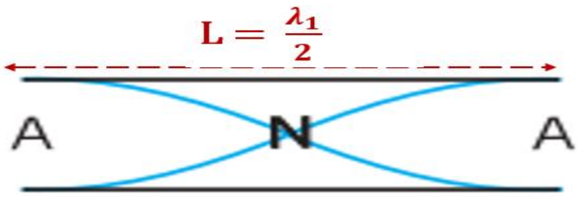
Thus only odd harmonics are possible in a closed pipe.

31.Draw the different modes of standing waves produced in an open pipe. Also obtain the frequencies of harmonics .
(or) Prove that the frquencies produced in an open pipe are in the ratio 1: 2: 3
(or) Show that all harmonics are possible in an open pipe.

Example for open pipe -Flute

Fundamental Mode or The First Harmonic

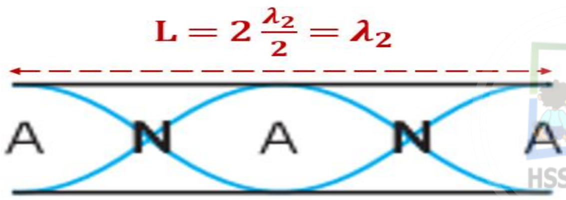
The oscillation mode with n=1 , the lowest frequency is called the fundamental mode or the first harmonic.



$$L = \frac{\lambda_1}{2}$$
$$\lambda_1 = 2L$$
$$\text{Frequency, } \nu_1 = \frac{v}{\lambda_1}$$
$$\nu_1 = \frac{v}{2L} \text{------------}(1)$$

The Second Harmonic

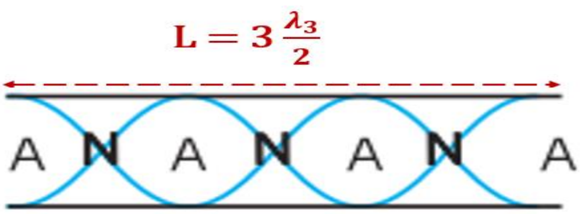
The second harmonic is the oscillation mode with n = 2.



$$L = 2\frac{\lambda_2}{2}$$
$$\lambda_2 = L$$
$$\text{Frequency, } \nu_2 = \frac{v}{\lambda_2}$$
$$\nu_2 = \frac{v}{L}$$
$$\nu_2 = 2\frac{v}{2L} \text{------------}(2)$$
$$\nu_2 = 2\nu_1$$

The Third Harmonic

The third harmonic is the oscillation mode with n = 3.



$$L = 3\frac{\lambda_3}{2}$$
$$\lambda_3 = \frac{2L}{3}$$
$$\text{Frequency, } \nu_3 = \frac{v}{\lambda_3}$$
$$\nu_3 = \frac{v}{\frac{2L}{3}}$$
$$\nu_3 = 3\frac{v}{2L} \text{------------}(3)$$
$$\nu_3 = 3\nu_1$$
$$\nu_1 : \nu_2 : \nu_3 = 1 : 2 : 3$$

Thus all harmonics are possible in an open pipe.

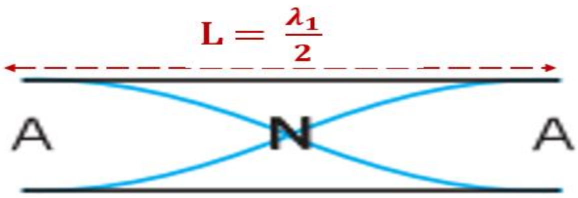
32.Why open pipes are preferred over closed pipes in musical instruments?

All harmonics are possible in an open pipe, but in a cloed pipe only odd harmonics are possible.

So open pipes are preferred over closed pipes in musical instruments.

33.Show that the frequency of fundamental mode(first harmonic) of an open pipe is twice that of a closed pipe.

Fundamental frequency of open pipe



$$L = \frac{\lambda_1}{2}$$

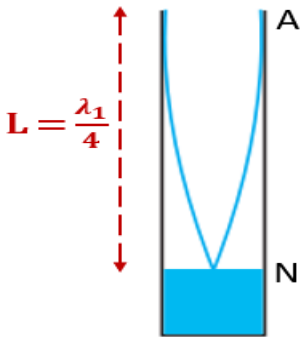
$$\lambda_1 = 2L$$

$$\text{Frequency, } \nu_1 = \frac{v}{\lambda_1}$$

$$\nu_1 = \frac{v}{2L} \text{------------(1)}$$

Fundamental frequency for closed pipe,

The oscillation mode with n=0 , fundamental mode or the first harmonic.



$$L = \frac{\lambda_1}{4}$$

$$\lambda_1 = 4L$$

$$\text{Frequency, } \nu_1 = \frac{v}{\lambda_1}$$

$$\nu_1 = \frac{v}{4L} \text{------------(2)}$$

From eq (1) and (2),Fundamental frequency of open pipe is twice that of a closed pipe.

34.What are beats?

The waxing and waning (periodinc wavering) of sound intensity when two waves of nearly same frequencies and amplitudes travelling in the same direction, are superimposed on each other is called beats.

If v_1 *and* v_2 are the frequencies of superposing waves, the beat frequency

$$\boldsymbol{\nu_{beat} = \nu_1 - \nu_2}$$

Seema Elizabeth
HSST Physics
MARM Govt HSS Santhipuram
Thrissur