

SAMPLE QUESTION PAPER – C

1. $1 \text{ kWh} = 1000 \times 3600 \text{ Ws} = 3.6 \times 10^6 \text{ J}$. 1
2. The normal force exerted by a liquid on any surface is called thrust. 1
3. (a) $PV^\gamma = \text{constant}$ of $TV^{\gamma-1} = \text{constant}$. $\frac{1}{2}$
 (b) $W = -nC_v(T_f - T_i)$. $\frac{1}{2}$
4. The strong smelling molecules of a gas move rapidly to intermingle with air molecules through the surrounding. This process takes little longer time because of collision of gas and air molecules. This keeps the odour persisting for some time. 1
5. Condition (i) is not sufficient, because it gives no reference of the direction of acceleration, whereas in S.H.M. the acceleration is always in a direction opposite to that of the displacement. 1
6. It is not necessary that a precise measurement has to be more accurate.
 Let true value of certain length be 3 cm. This length is measured with a measuring instrument of limit or resolution of 0.1 cm and the measured value is obtained as 3.1 cm. This length is again measured with another measuring instrument of resolution 0.01 cm and the length is measured as 2.8 cm. 1
 In this case first measurement has more accuracy because it is closer to the true value but less precision because the resolution is only 0.1 cm whereas in the second one it was 0.01 cm.
7. This graph can be for a ball dropped vertically from a height d . It hits the ground with some downward velocity and bounces up to height $d/2$ where its upward velocity becomes zero. 2

Or

8. As the vectors $\vec{A} + \vec{B}$ and $\vec{A} - \vec{B}$ are perpendicular to each other, therefore 1

$$(\vec{A} + \vec{B}) \cdot (\vec{A} - \vec{B}) = 0$$

$$\vec{A} \cdot \vec{A} - \vec{A} \cdot \vec{B} + \vec{B} \cdot \vec{A} - \vec{B} \cdot \vec{B} = 0$$

or $A^2 - B^2 = 0$ 1

$\Rightarrow A = B, \quad (\because \vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A})$ 1

Or

Static friction comes into play when the horse applies force to start the motion in the cart, on the other hand, kinetic friction comes into play when the cart is moving. 2

9. (a) The inability of a body to change its state of uniform rotation about an axis is called rotational inertia or M.I. of the body. $\frac{1}{2}$
 It plays the same role in rotatory motion as is being played by the mass in translation motion, i.e., it is rotational analogue of mass. $\frac{1}{2}$
 (b) M.I. of a body about a fixed axis of rotation is defined as the sum of the products of the masses and square of the perpendicular distance of various constituent particles from the axis of rotation. 1
10. When a simple harmonic system oscillates with a constant amplitude which does not change with time, its oscillations are called undamped oscillations. When a simple harmonic system oscillates with a decreasing amplitude, with time its oscillations are called damped. 2
11. Let the measured values be :

$$\text{Mass of block } (m) = 39.3 \text{ g}$$

$$\text{Length of block } (l) = 5.12 \text{ cm}$$

$$\text{Breadth of block } (b) = 2.56 \text{ cm}$$

$$\text{Thickness of block } (t) = 0.37 \text{ cm}$$

$$\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{m}{l \times b \times t}$$

$$= \frac{39.3 \text{ g}}{5.12 \text{ cm} \times 2.56 \text{ cm} \times 0.37 \text{ cm}}$$

$$= 8.1037 \text{ g cm}^{-3}$$

Now,

$$\begin{aligned}\text{uncertainty in } m &= \pm 0.01 \text{ g} \\ \text{uncertainty in } l &= \pm 0.01 \text{ cm} \\ \text{uncertainty in } b &= \pm 0.01 \text{ cm} \\ \text{uncertainty in } t &= \pm 0.01 \text{ cm}\end{aligned}$$

1

Maximum relative error in the density value is, therefore given by

$$\frac{\Delta \rho}{\rho} = \frac{\Delta l}{l} + \frac{\Delta b}{b} + \frac{\Delta t}{t} + \frac{\Delta m}{m}$$

$$= \frac{0.01}{5.12} + \frac{0.01}{2.56} + \frac{0.01}{0.37} + \frac{0.1}{39.3}$$

$$= 0.0019 + 0.0039 + 0.027 + 0.0024$$

$$= 0.0358$$

1

Hence,

$$\rho = 0.0358 \times 8.1037 \approx 0.3 \text{ g cm}^{-3}.$$

We cannot, therefore, report the calculated value of ρ ($= 8.1037 \text{ gm}^{-3}$) upto the fourth decimal place. Since $\rho = 0.3 \text{ g cm}^{-3}$ the value of ρ can be regarded as accurate upto the first decimal place only. Hence the value of ρ must be rounded off as 8.1 g cm^{-3} and the result of measurements should be reported as $\rho = (8.1 \pm 0.3) \text{ g cm}^{-3}$.

1

12. As the ball is moving under the effect of gravity, the direction of acceleration due to gravity remain vertically downwards.

(b) If the ball is at the highest point of its motion, its velocity becomes zero and the acceleration is equal to the acceleration due to gravity $= 9.8 \text{ ms}^{-2}$ in vertically downward direction. $\frac{1}{2}$

(c) If the highest point is chosen as the location for $x = 0$ and $t = 0$ and vertically downward direction to be the positive direction of x -axis.

Four upward motion, sign of position is negative, sign of velocity negative and the sign of acceleration positive, i.e., $v < 0$, $a > 0$. $\frac{1}{2}$

For downward motion, sign of position is positive, sign of velocity is positive and the sign of acceleration is also positive, i.e., $v < 0$, $a > 0$. $\frac{1}{2}$

(d) Suppose, t = time taken by the ball to reach the highest point.

H = height of the highest point from the ground.

During vertically upward motion of the ball,

$\therefore$ Initial velocity, $u = -29.4 \text{ ms}^{-2}$

$$a = g = 9.8 \text{ ms}^{-2}.$$

Final velocity $v = 0$, $s = H = ?$, $t = ?$

Applying the relation, $v^2 - u^2 = 2as$, we get

$$0^2 - (29.4)^2 = 2 \times 9.8 H$$

or

$$H = -\frac{29.4 \times 29.4}{2 \times 9.8} = -44.1 \text{ m},$$

where negative sign indicates that the distance is covered in upward direction.

Using relation

$$v = u + at, \text{ we get}$$

$$0 = -29.4 + 9.8 \times t$$

 $\therefore$

$$t = \frac{29.4}{9.8} = 3 \text{ s}.$$

i.e.,

Time of ascent = 3 s.

It is also well known that when the object moves under the effect of gravity alone, the time of ascent is always equal to the time of descent.

∴ Total time after which the ball returns to the player's hand
 $= 2t = 2 \times 3 = 6 \text{ s.}$

13. Step I : Using

$$H = \frac{u^2 \sin^2 \theta}{2g} \quad \frac{1}{2}$$

when
and

$$H = 25 \text{ m, } u = 40 \text{ m/s}$$

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

$$25 = \frac{40^2 \sin^2 \theta}{2 \times 9.8} \quad \frac{1}{2}$$

i.e.,

$$\sin^2 \theta = \frac{490}{40^2}$$

$$\sin \theta = \frac{\sqrt{490}}{40} = 0.5534$$

i.e.,

$$\theta = 33.6^\circ \quad 1$$

Step 2 :

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

$$R = \frac{40^2 \sin 2(33.6)}{9.8}$$

$$= \frac{40^2 \sin 67.2}{9.8} = \frac{40^2 \times 0.9219}{9.8}$$

$$= 150.514 \quad 1$$

14. Given,

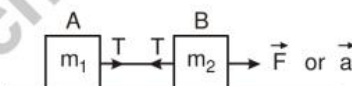
Suppose
and

be the masses lying on a frictionless horizontal table.

$$F = 600 \text{ N}$$

$$m_1 = 10 \text{ kg}$$

$$m_2 = 20 \text{ kg}$$



Suppose T be tension in the string and 'a' be the acceleration of the system, in the direction of force applied.

(a) If force is applied on the heavier mass.

Then equation of motion of A and B are

$$m_1 a = T \quad \dots(i)$$

$$m_2 a = F - T \quad \dots(ii)$$

Dividing equation (ii) by equation (i), we get

$$\frac{m_2}{m_1} = \frac{F - T}{T} = \frac{F}{T} - 1 \quad \frac{1}{2}$$

⇒

$$\frac{20}{10} = \frac{F}{T} - 1$$

⇒

$$\frac{F}{T} = 2 + 1 = 3$$

⇒

$$T = \frac{F}{3}$$

$$\begin{aligned} &= \frac{600}{3} \\ &= 200 \text{ N} \end{aligned} \quad \frac{1}{2}$$

(b) If the force is applied on lighter mass :



Suppose T be the tension in the string in this case, then equations of motion of A and B are,

$$F - T = m_1 a \quad \dots(iii)$$

and

$$T = m_2 a \quad \dots(iv) \quad \frac{1}{2}$$

Equations (iii) and (iv) give

$$\frac{F - T}{T} = \frac{m_1 a}{m_2 a}$$

$$\Rightarrow \frac{F}{T} - 1 = \frac{m_1}{m_2} = \frac{10}{20} = \frac{1}{2}$$

$$\Rightarrow \frac{F}{T} = 1 + \frac{1}{2} = \frac{3}{2}$$

$$\begin{aligned} \Rightarrow T &= \frac{3}{2} F = \frac{2}{3} \times 600 \\ &= 400 \text{ N} \end{aligned} \quad \frac{1}{2}$$

$$\Rightarrow T = \frac{2}{3} \times 600 = 400 \text{ N} \quad \frac{1}{2}$$

15. According to the principle of conservation of the total kinetic energy for elastic collision,
initial kinetic energy = final kinetic energy 1

Here, $\text{initial kinetic energy} = \frac{1}{2} m (200)^2 + \frac{1}{2} M (0)^2$

$$= \frac{1}{2} m (200)^2 \quad 1$$

where m is the mass of the molecule and M is the mass of the container.

and $\text{final kinetic energy} = \frac{1}{2} m (200)^2 + \frac{1}{2} M (0)^2$

$$= \frac{1}{2} m (200)^2 \quad 1$$

Thus principle of total kinetic energy is obeyed.

16. Using equation for position vector,

$$\vec{r} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2}{m_1 + m_2}$$

Let $\vec{r} = 0$, 1

then $m_1 \vec{r}_1 + m_2 \vec{r}_2 = 0$

i.e., $m_2 \vec{r}_2 = - m_1 \vec{r}_1$

i.e., $\vec{r}_2 = - \frac{m_1}{m_2} \vec{r}_1$ 1

Clearly, $\vec{r}_2$ and $\vec{r}_1$ are opposite to each other. It indicates when centre of mass lies on origin, m_1 lies on the left side of origin and m_2 on the right side, i.e., they lie on a straight line. 1

17. As Kepler's third law,

$$\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3} \quad \frac{1}{2}$$

Let 1 denotes planet and 2 denotes earth

$$R_1^3 = \frac{T_1^2}{T_2^2} \times R_2^3 \quad 1$$

As the planet is revolving twice as fast as earth,

$$T_1 = \frac{T_2}{2}$$

$$\Rightarrow R_1^3 = \left(\frac{T_2}{2}\right)^2 \times (1\text{A})^2$$

$$\Rightarrow R_1^3 = \frac{1}{4} \text{AU}^3$$

$$R_1 = \left(\frac{1}{4}\right)^{1/3} \text{AU}$$

$$R_1 = \frac{1}{\sqrt[3]{4}} \text{AU}$$

$$R_1 = 0.62996 \text{ A.U.} = 0.63 \text{ A.U.} \quad 1$$

This result can be stated as the orbital radius of planet is 0.63 times the orbital radius of earth. $\frac{1}{2}$

18. (i) (a) Using

$$F = ky. \quad \frac{1}{2}$$

The maximum extension,

$$y = \frac{F}{k} \quad \frac{1}{2}$$

(b) Here the springs has no rigid support so each mass behaves as a support for the spring against force applied on the other end.

$$\therefore \text{Maximum extension, } y = \frac{F}{k} \quad \frac{1}{2}$$

$$(ii) (a) \text{ Here, time period, } T = 2\pi\sqrt{\frac{M}{k}} \quad \frac{1}{2}$$

(b) Here the spring is considered of two halves and the time period of the arrangement is depending upon half spring. When a spring of constant k is cut into two equal halves, the force constant of each half becomes $2k$.

$$\therefore \text{Time period, } T = 2\pi\sqrt{\frac{M}{2k}} \quad 1$$

Or

Node (N) is a point where the amplitude of oscillation is zero (and pressure is maximum).

Antinode (A) is a point where the amplitude of oscillation is maximum (and pressure is minimum).

These nodes and antinodes does not coincide with pressure nodes and antinodes. 1

In fact, N coincides with pressure antinode and A coincides with pressure node, as is clear from the definitions. 1

The separation between a node and nearest antinode is $\lambda/4$.

As the phase difference between two points separated by λ is 2π radian, therefore/phase difference between two points separated by $\lambda/10$ is $2\pi/10 = \pi/5$ radian. 1

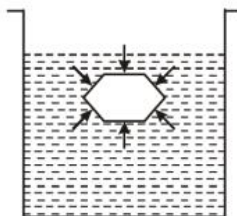
19. It states, the change in pressure is produced in any part of an enclosed fluid, the same is transmitted equally to all points of liquid in all directions. 1

Or

Imaging the effect of gravity, pressure in a fluid at rest is the same at all points.

Or

Equal pressure is exerted by a liquid in all directions.

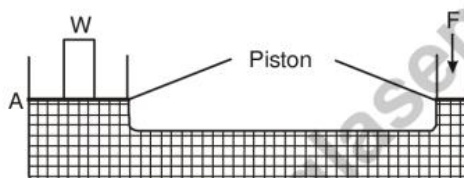


Applications : This principle is used to manufacture hydraulic lift. It consist of two cylinders, one of larger area of cross-section A and the other smaller a . Force is applied to smaller piston to produce a pressure.

$$P = F/a$$

$\frac{1}{2}$

As per Pascal's law same pressure is transmitted to larger piston, then $W = P \times A$.



Clearly large area A is producing more lifting force W .

Hydraulic brakes are also based upon Pascal's law where transmitted to brake drum.

The large force then operates the brake shoe. 1

20. (a) Stream line flow of a liquid is that flow in which every particle of the liquid follows exactly the path of its preceding particle and has the same velocity in magnitude and direction as that of its preceding particle while crossing through that point.

The stream line flow is accompanied by stream lines. 1

A stream line is the actual path followed by the procession of particles in a steady flow, which may be straight or curved such that tangent to it at any point indicates the direction of flow of liquid at the point.

(b) Important properties of stream lines : $\frac{1}{2}$

(i) In a stream line flow, no two stream lines can cross each other. If they do so, the particles of the liquid at the point of intersection will have two different directions for their flow, which will destroy the steady nature of the liquid flow.

(ii) The greater is the crowding of stream lines at a place, the greater is the velocity of liquid particles at that place and vice-versa. 1

21. Joule observed that amount of mechanical work W when disappeared leappens in the form of heat, i.e.,

$$W \propto H$$

or

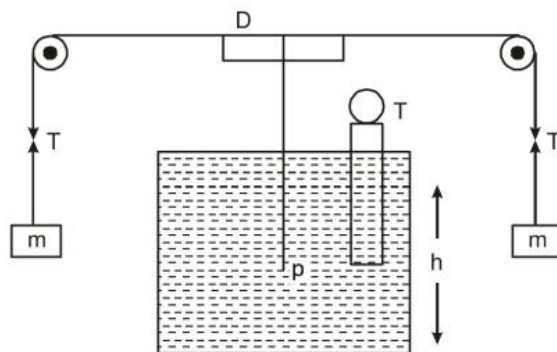
$$W = JH$$

or

$$J = \frac{W}{H} = 4.18 \text{ J cal}^{-1}$$

1

He made two equal weights to fall through some heights. This makes the drum D rotate and thus paddle P chowns water inside the calorimeter. $\frac{1}{2}$



This makes the water heated up. The rise in temperature is noted with thermometer T. The height of fall of weights helps in working out the mechanical work W. The temperature helps in calculating the heat energy H. It was observed that,

$$W \propto H. \quad 1$$

22. (a) **Kelvin's statement** : It is not possible to have continuous work by cooling a body to a temperature. Lower than that of coldest of its surroundings. 1

Celsius statement : It is not possible to transfer heat from a body at lower temperature to another at higher temperature without the help of some external energy. 1

(b) It is defined as the ratio of the amount of heat removed in a cycle from the refrigerator to the work done by some external agency to help the removal of this heat, i.e.,

$$\beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} \quad \frac{1}{2}$$

Also,

$$\beta = \frac{T_2}{T_1 - T_2}$$

For higher efficiency of refrigerator β should be higher. 1

23. (a) Sabita is sincere and hard working and having scientific temper. 2

(b) $[k = k_1 k_2 / (k_1 + k_2)]$; $T = 2\pi \sqrt{m(k_1 + k_2) / k_1 k_2}$. 2

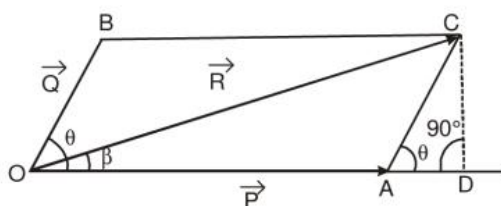
24. It states that if two vectors can be represented completely (i.e., both in magnitude and direction) by the two adjacent sides of a parallelogram drawn from a point then their resultant is represented completely by its diagonal drawn from the same point. 1/2

Proof: Let $\vec{P}$ and $\vec{Q}$ be the two vectors represented completely by the adjacent sides OA and OB of the parallelogram OACB s.t.,

$$\vec{OA} = \vec{P}, \vec{OB} = \vec{Q}$$

or

$$OA = P, OB = Q$$



$\theta =$ angle between them $\angle AOB$

If R be their resultant, then it will be represented completely by the diagonal OC through point O s.t., $\vec{OC} = \vec{R}$.

Magnitude of $\vec{R}$: Draw $CD \perp$ to OA produced

$$\therefore \angle DAC = \angle AOB = \theta$$

Now in right angled triangle ODC,

$$\begin{aligned} OC^2 &= OD^2 + DC^2 \\ &= (OA + AD)^2 + DC^2 \\ &= OA^2 + AD^2 + 2OA \cdot AD + DC^2 \\ &= OA^2 + (AD^2 + DC^2) + 2OA \cdot OD \end{aligned} \quad \dots(i)$$

Also in right angled triangle ADC,

$$AC^2 = AD^2 + DC^2 \quad \dots(ii)$$

Also,

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

Or

$$AD = AC \cos \theta \quad \dots(iii)$$

and

$$\frac{DC}{AC} = \sin \theta$$

Or

$$DC = AC \sin \theta \quad \dots(iv)$$

$\therefore$ From eqns. (i), (ii), (iii), we get

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

Or

$$OC = \sqrt{OA^2 + AC^2 + 2OA \cdot AC \cos \theta} \quad \dots(v)$$

As

$$OC = R, OA = P, AC = OB = Q \quad \dots(vi)$$

$\therefore$ From equations (v) and (vi), we get

$$R = \sqrt{P^2 + Q^2 + 2PQ \cos \theta} \quad \dots(vii)$$

Equation (iii) gives the magnitude of $\vec{R}$.

1

Direction of R : Let β the angle made by R with $\vec{P}$.

$\therefore$ In right angled triangle ODC,

$$\begin{aligned} \tan \beta &= \frac{DC}{OD} = \frac{DC}{OA + AD} \\ &= \frac{AC \sin \theta}{OA + AC \cos \theta}, \end{aligned} \quad \text{[by using (iii) and (iv)]}$$

$$\tan \beta = \frac{Q \sin \theta}{P + Q \cos \theta} \quad \dots(viii)$$

Special cases : (a) When two vectors are acting in same direction, then

$$\theta = 0^\circ$$

$\therefore$

$$\begin{aligned} R &= \sqrt{(P+Q)^2} \\ &= P + Q \end{aligned}$$

and

$$\tan \theta = \frac{Q \cdot 0}{P + Q} = 0$$

Or

$$\beta = 0^\circ$$

Thus, the magnitude of the resultant vector is equal to the sum of the magnitudes of the two vectors acting in the same direction and their resultant acts in the direction of P and Q. 1

(b) When two vectors act in the opposite, then

$$\theta = 180^\circ$$

$\therefore$

$$\cos \theta = -1 \text{ and } \sin \theta = 0$$

$\therefore$

$$\begin{aligned} R &= \sqrt{P^2 + Q^2 + 2PQ(-1)} \\ &= \sqrt{P^2 + Q^2 - 2PQ} \end{aligned}$$

$$= \sqrt{(P-Q)^2} \text{ or } \sqrt{(Q-P)^2}$$

$$= (P-Q) \text{ or } (Q-P)$$

and

$$\tan \beta = \frac{Q \times 0}{P+Q(-1)} = 0$$

$$= \tan 0 \text{ or } \tan 180^\circ$$

$\therefore$

$$\beta = 0^\circ \text{ or } 180^\circ.$$

Thus, the magnitude of the resultant of two vectors acting in the opposite direction to the difference of the magnitude of two vectors and it acts in the direction of bigger vector. 1

(c) If $\theta = 90^\circ$, i.e., if $\vec{P} \perp \vec{Q}$, then $\cos 90^\circ = 0$

and

$$\sin 90^\circ = 1$$

$\therefore$

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

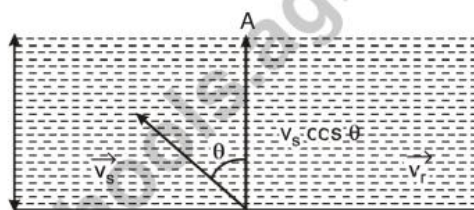
and

$$\tan \beta = \frac{0}{P}$$

1

24. Let $\vec{v}_s$ and $\vec{v}_r$ be the velocities of swimmer and river respectively.

Let $\vec{v}$ = resultant velocity of v_s and v_r .



(i) Let the swimmer begins to swim at an angle θ with the line OA where OA is $\perp$ to the flow of river.

If t = time taken to cross the river, then,

$$t = \frac{l}{v_s \cos \theta} \quad \frac{1}{2}$$

where l = breadth of river

For t to be minimum, $\cos \theta$ should be maximum,

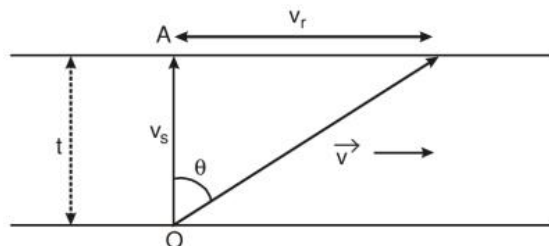
i.e.,

$$\cos \theta = 1.$$

This is possible, if

$$\theta = 0.$$

Thus, we conclude that the swimmer should swim in a direction $\perp$ to the direction of flow of river.



(ii) $v = \sqrt{v_s^2 + v_r^2}$

(iii) $\tan \theta = \frac{v_r}{v_s} = \frac{X}{l}$

or $X = l \frac{v_r}{v_s}$ 1/2

(iv) $t = \frac{l}{v_s}$ 1/2

(b) It is defined as a vector having zero magnitude and acting in the arbitrary direction. It is denoted by $\vec{O}$. 1/2

Properties of null vector :

(i) The addition or subtraction of zero vector from a given vector is again the same vector.

i.e., $\vec{A} + \vec{O} = \vec{A}$

$\vec{A} - \vec{O} = \vec{A}$ 1/2

(ii) The multiplication of zero vector by a non-zero real number is again the zero vector.

i.e., $n \vec{O} = \vec{O}$ 1/2

(iii) If $n_1 \vec{A} = n_2 \vec{B}$

As the body is rigid, angular acceleration α of all the particles of the body is the same. However, their linear accelerations of the particle from the axis. If $a_1, a_2, a_3, \dots, a_n$ are the respective linear accelerations of the particle, then

$$a_1 = r_1 \alpha, a_2 = r_2 \alpha, a_3 = r_3 \alpha, \dots \quad 1$$

Force on particle of mass m , is

$$f_1 = m_1 a_1 = m_1 r_1 \alpha$$

Moment of this force about the axis of rotation

$$f_1 \times r_1 = (m_1 r_1 \alpha) \times r_1 = m_1 r_1^2 \alpha \quad 1$$

Similarly, moment of forces on other particles about the axis of rotation are $m_2 r_2^2 \alpha, m_3 r_3^2 \alpha, \dots, m_n r_n^2 \alpha$.

$\therefore$ Torque acting on the body,

$$\tau = m_1 r_1^2 \alpha + m_2 r_2^2 \alpha + m_3 r_3^2 \alpha, \dots, m_n r_n^2 \alpha$$

$$\tau = (m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + m_n r_n^2) \alpha$$

So,

$$\tau = \left(\sum_{i=1}^{i=n} m_i r_i^2 \right) \alpha$$

$$\tau = I \alpha$$

1

where $m_1 r_1^2$ = moment of inertia of this body about the given axis of rotation.

If $\alpha = 1, \tau = 1 \times 1$ or $I = \tau$

$$\vec{\tau} = I \vec{\alpha}$$

1

Or

Kinetic energy of rotation :

K.E. of rotation of a body is the energy possessed by the body on account of its rotation about a given axis. 1/2

If figure, we have shown a rigid body rotating in xy plane about z -axis with a uniform angular velocity ω .

Let the body consists of particles of masses $m_1, m_2, m_3, \dots, m_n$ at distances $r_1, r_2, r_3, \dots, r_n$ respectively. Let the linear velocity of different particles are $v_1, v_2, v_3, \dots, v_n$. 1/2

$$v_1 = r_1 \omega$$

$$v_2 = r_2 \omega$$

$$v_3 = r_3 \omega, \dots$$

1

K.E. of particle mass m_1 is

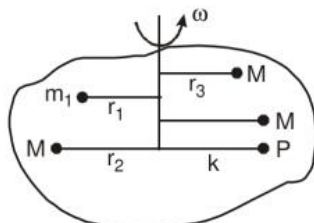
$$\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m (r_1 \omega)^2$$

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

1/2

Similarly, K.E. of other particles of the body are :

$$\frac{1}{2} m_2 r_2^2 \omega^2, \frac{1}{2} m_3 r_3^2 \omega^2, \dots$$



Axis of rotation

$$\therefore \text{K.E. of rotation of the body} = \frac{1}{2} m_1 r_1^2 \omega^2 + \frac{1}{2} m_2 r_2^2 \omega^2 + \frac{1}{2} m_3 r_3^2 \omega^2 + \dots$$

$$= \frac{1}{2}(m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \dots) \omega^2$$

$$= \frac{1}{2} \left(\sum_{i=1}^{i=n} \frac{1}{2} m_i r_i^2 \right) \omega^2 \quad \dots(1)$$

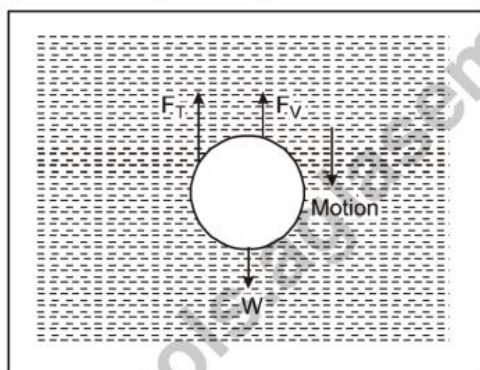
$$= \frac{1}{2} I \omega^2$$

i.e., K.E. of rotation = $\frac{1}{2} I \omega^2$,

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

26. Terminal velocity : It is maximum constant velocity acquired by the body while falling freely in a viscous medium.

When a small spherical body falls freely through a viscous medium, three forces act on it.



(i) Weight of the body acting vertically downwards. 1/2

(ii) Upward thrust due to buoyancy equal to weight of liquid displaced. 1/2

(iii) Viscous drag acting in the direction opposite to the motion of body. According to Stoke's law, $F \propto v$, i.e., the opposing viscous drag goes on increasing with the increasing velocity of the body. 1/2
As the body falls through a medium, its velocity goes on increasing due to gravity. Therefore, the opposing viscous drag which acts upwards also goes on increasing. A stage reaches when the true weight of the body is just equal to the sum of the upward thrust due to buoyancy and the upward viscous drag. At this stage, there is no net force to accelerate the body. Hence it starts falling with a constant velocity, which is called terminal velocity.

Let ρ be the density of the material of the spherical body of radius r and ρ_0 be the density of the medium.

$\therefore$ True weight of the body,

$$W = \text{volume} \times \text{density} \times g = \frac{4}{3} \pi r^3 \rho g$$

Upward thrust due to buoyancy,

$F_T = \text{weight of the medium displaced}$

$$\therefore F_T = \text{volume of the medium displaced} \times \text{density} \times g = \frac{4}{3} \pi r^3 \rho_0 g \quad 1$$

If v is the terminal velocity of the body, then according to Stoke's law.

$$\text{upward viscous drag } F_V = 6\pi\eta r v$$

When body attains terminal velocity, then

$$F_T + F_V = W$$

$$\therefore \frac{4}{3}\pi r^3 \rho_0 g + 6\pi \eta r v = \frac{4}{3}\pi r^3 \rho g$$

$$\text{Or } 6\pi \eta r v = \frac{4}{3}\pi r^3 (\rho - \rho_0) g$$

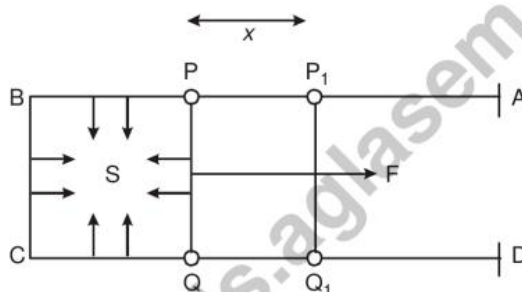
$$\text{Or } v = \frac{2r^2(\rho - \rho_0)g}{9\eta} \quad 1$$

It depends upon the terminal velocity varies directly as the square of the radius of the body and inversely as the coefficient of viscosity of the medium. It also depends upon densities of the body and the medium. 1

Or

Surface energy is defined as the amount of the work done against the force of surface tension, in forming the liquid surface of a given area at a constant temperature. 1

To obtain an expression for surface energy, take a rectangular frame ABCD having a wire PQ which can slide along the sides AB and CD. Dip the frame in soap solution and form a soap film BCQP on the rectangular frame. There will be two free surfaces of film where air and soap are in contact. 1/2



Let S = surface tension of the soap solution.
 l = length of the wire PQ.

Since there are two free surfaces of the film and surface tension acts on both of them, hence total inward force on the wire PQ is

$$F = S \times 2l \quad 1/2$$

To increase the area of the soap film we have to pull the sliding wire PQ outwards with a force F . Let the film be stretched by displacing wire PQ through a small distance x to the position P_1Q_1 . The increase in area of film PQQ_1P_1

$$\begin{aligned} &= a \\ &= 2(l \times x) \quad 1/2 \end{aligned}$$

$\therefore$ Work done in stretching film is,

$$\begin{aligned} E &= \text{force applied} \times \text{distance moved} \\ &= (S \times 2l) \times x \\ &= S \times (2lx) \\ &= S \times a, \quad 1/2 \end{aligned}$$

where $2lx = a$ = increase in area of the film in both sides. 1/2

$\therefore l \times x$ = increase in area of film on both sides.

If temperature of the film remains constant in this process, this work done is stored in the film as its surface energy. 1

