# ROTATORY MOTION

## 3. TORQUE AND ANGULAR MOMENTUM

**POINTS TO REMBER**

1. **Torque: -** Torque is defined as the product of force and perpendicular distance of the point of application of force from the point.

   **Units:** N –m **Dimensional formula**: $\left[ML^2T^{-2}\right]$

   It is a vector quantity and directed along the axis of rotation.

2. **Couple: - (C)** Two equal unlike and non collinear forces acting on a body constitute a couple which produce rotation.

3. Moment of couple is defined as a product of either of the forces and perpendicular distance between their lines of action.

   **unit:** Nm **Dimensional formula :** $\left[ML^2T^{-2}\right]$

4. Angular momentum: - The moment of linear momentum of a particle about a fixed point is called angular momentum about that point. $L = I\omega$

   **Unit:** $kgm^2s^{-1}$ (or) JS **Dimensional formula**: $\left[ML^2T^{-1}\right]$

5. **Conservation of angular momentum:** When there is no resultant external torque on a rotating system, the angular momentum of the system remains constant both in magnitude and direction.

6. Work done = Increase in kinetic energy $= \frac{1}{2} I\left(\omega_f^2 - \omega_i^2\right)$

| **Translatory motion** | **Rotatory motion** |
|---|---|
| Mass (m) | Moment of inertia (I) |
| F = ma | Torque $\tau = I\alpha$ |
| Impulse = Ft | Angular impulse = $\tau\ t$ |
| Linear momentum p = mv | Angular momentum L = I $\omega$ |
| Work = FS | $W = \tau\theta$ |
| Power = FV | $P = \tau\omega$ |
| $m_1v_1 = m_2v_2$ | $I_1\omega_1 = I_2\omega_2$ |
| $E = \frac{p^2}{2m}$ | $E = \frac{L^2}{2I}$ |
| $KE = \frac{1}{2} m v^2$ | Rotational KE = $\frac{1}{2} I\omega^2$ |

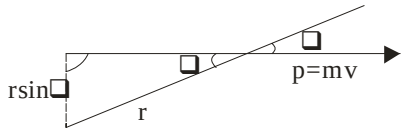
**Short Answer Questions:**

1. **Define angular momentum. State its units and dimension.**

A. Moment of linear momentum of a body is called angular momentum.

Let P be the linear momentum and r be the position vector of a particle from the given point 'O'.

Angular momentum $\left(\bar{L}\right) = \bar{r} \times \bar{p} = rp\sin\theta = r\left(mv\right)\sin\theta$




If the line of motion is perpendicular, (or) $\theta = 90°$

$L = mvr = m\left(r\omega\right)r = mr^2\omega$

(or) $L = I\omega$

**Unit:** $kgm^2s^{-1}$ (or) JS

**Dimension:** $\left[ML^2T^{-1}\right]$

**2. State and prove the principle of conservation of angular momentum.**

**A.** **Statement:** When there is no resultant external torque on a rotating system, the angular momentum of the system remains constant both in magnitude and direction.

**Proof:** The angular momentum 'L' and torque '$\tau$' acting on a rotating system are related as $\tau = \frac{dL}{dt}$

(The rate of change in angular momentum of a rotating system is known as torque)

If there is no external torque on the system, $\frac{dL}{dt} = 0$ and hence 'L' is constant.

**3. Explain the principle of conservation of angular momentum with examples. (2008-March)**

**A.** 1) A person stands on a turn table with dumb – bells in has stretched hands and the turn table rotates with a constant angular velocity $\omega$. Now when the person brings his hands closer to his body, his moment of inertia decreases and hence the angular velocity increases since $I\omega =$ const. according to the law of conservation of angular momentum.

2) A ballet dances can increase (or) decreases her angular speed by stretching her hands (or) bringing her hands closer to the body. When the hands are outstretched moment of inertia increases and angular speed decreases sing $I\omega =$ constant.

3) When a diver jumps from a diving board with his legs and hands cut stretched. When the legs and hands are brought closer to the body moment of inertia decreases and angular speed increases. When the reaches the water, legs and hands are out stretched so that moment of inertia according to $I\omega =$ constant.

**20. A hollow sphere and a solid sphere of some mass and radius rotate about the diameter. Which one will have grater moment of inertia? Justify your answer.**

A. **M.I of a solid sphere about its diameter is** $\frac{2}{5}mR^2$

M.I. of a hollow sphere about its diameter is $\frac{2}{3}mR^2$

Since $\frac{2}{5}mR^2 < \frac{2}{3}mR^2$

Hence M.I of hollow sphere is more.

**4. A hollow sphere and a solid sphere of same mass and material rotate about the diameter. Which one will have greater moment of inertia ? Explain.**

**A.** Since both the spheres are made of same material and equal mass the hollow sphere has more radius. Since moment of inertia directly proportional to the square of radius, M.I of hollow sphere is more.

**Very Short Answer Questions:**

**1. Define torque. State its units.**

**A.** **Definition:** Torque about a fixed point is defined as product of the force and perpendicular distance of the point of application of the force from the fixed point.
Unit: N –m

**2. Which of the following are vectors?**
**i) Torque, ii) Moment of the couple, iii) Angular momentum.**

**A.** All the given quantities are pseudo vectors.

**3. Is Torque a vector or a scalar? If it is a vector give its direction.**

**A.** Torque is a pseudo vector whose direction is perpendicular to the plane containing force vector and radius vector. It is given by right hand screw rule.

**4. Is angular momentum a vector or a scalar? If it is a vector give its direction.**

**A.** Angular momentum is a pseudo vector perpendicular to the plane of rotation whose direction is given by right hand screw rule.

**5. Give the vector form of the relation between v and ω**

**A.** $\bar{V} = \bar{\omega} \times \bar{r}$

**6. Give the vector form of the relation between a and α.**

**A.** $\bar{a} = \bar{\alpha} \times \bar{r}$

**7. i) Give the vector form of the relation between** $\tau$ *and* $F$
**ii) Give the vector form of the relation between L and p.**

**A.** **i)** $\bar{\tau} = \bar{r} \times \bar{F}$ and **ii)** $\bar{L} = \bar{r} \times \bar{p}$ .

**8. Two rigid bodies have same angular momentum about their axis of rotation. Which of the bodies will have greater kinetic energy?**

**A.** $E = \frac{L^2}{2I}$. If the **angular momentum is same, then the** body with lesser M.I. has greater KE

**9. Two rigid bodies have same moment of inertia about their axes of symmetry. Which will have greater kinetic energy?**

**A.** $E = \frac{L^2}{2I}$. If the **moment of inertia is same, then the body** with greater angular momentum has **greater kinetic energy.**

**10. Derive the relation between torque and angular momentum.(2006March)**

**A.** The rate of change in angular momentum of a rotating system is known as torque. The angular momentum 'L' and torque '$\tau$' acting on a rotating system are related as $\tau = \frac{dL}{dt}$

If there is no external torque on the system, $\frac{dL}{dt} = 0$ and hence 'L' is constant.

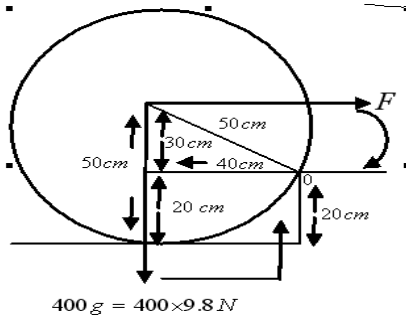
**Exercise 1**

**1. When a force of 10.0 N is exerted on the handle of a door, the door can be just opened. If the handle is a distance of 50 cm from the hinges find the torque applied on the door.**

Sol: F = 10 N, r = 50 cm = 0.5 m and $\theta = 90°$

The torque $(\tau) = F\, r \sin\theta = 10 \times 0.5 \times \sin 90° = 5\, N\, m.$

**2. A roller of mass 300 kg rests against a step of height 20 cm. If the radius of the roller is 50 cm, find the force to be applied passing through its centre of mass to take the roller on to the step.**




Sol : Taking the moments of forces about 'O'

. $300 \times 9.8 \times 0.4 = F \times 0.3$

$F = \frac{300 \times 9.8 \times 4}{3} = 392\, N.$

**3. A uniform rod of length $l$ is held vertical on a horizontal floor. Fixing its lower end, the rod is allowed to fall onto the ground. Find (i) its KE just before coming into contact with the ground and (ii) its angular frequency at that instant.( March 2011 )**

Sol : When a uniform rod is held in the vertical position ,

Potential energy of the rod = $Mg\frac{l}{2}$. $(\because h = l/2)$

When the rod is allowed to fall down fixing its lower end, the moment of inertia of the rod rotating about one end and perpendicular to its length, . $I = \frac{Ml^2}{3}$

i) Its rotational kinetic energy $= \frac{1}{2} I\omega^2 = \frac{1}{2}\left(\frac{Ml^2}{3}\right)\omega^2$

where $\omega$ is the angular frequency just before coming into contact with the ground.

Now, Rotational kinetic energy = potential energy of the rod

$\frac{1}{2}\left(\frac{Ml^2}{3}\right)\omega^2 = Mg\frac{l}{2}$

Angular frequency, $\omega = \sqrt{\frac{3g}{l}}$.

**4. What is the work done in increasing the angular frequency of a circular ring of mass 2 kg and radius 25 cm from 10 rpm to 20 rpm about its axis?**

Sol : $M = 2kg; R = 25cm = 0.25m;$ *MI of a circular ring*, $I = MR^2$

$$\omega_i = \frac{2\pi n}{t} = \frac{2\pi \times 10}{60} = \frac{\pi}{3} rad\ s^{-1}$$

$$\omega_f = \frac{2\pi n}{t} = \frac{2\pi \times 10}{60} = \frac{2\pi}{3} rad\ s^{-1}$$

Work done = Increase in kinetic energy $= \frac{1}{2} I\left(\omega_f^2 - \omega_i^2\right) = \frac{1}{2} MR^2\left(\omega_f^2 - \omega_i^2\right)$

$$= \frac{1}{2} \times 2 \times (0.25)^2 \left( \left(\frac{2\pi}{3}\right)^2 - \left(\frac{\pi}{3}\right)^2 \right)$$

$$= 0.0625\left(\frac{\pi^2}{3}\right) = 0.2058\, J.$$

**5. The angular frequency of a fan of moment of inertia 0.1 kg $m^2$ is increased from 30 rpm to 60 rpm when a torque of 0.03 N m acts on it. Find the number revolutions made by the fan while the angular frequency is increased from 30 rpm to 60 rpm.**

Sol :

$$\omega_i = \frac{2\pi \times 30}{60} = \pi\ rad\ s^{-1}; \omega_2 = \frac{2\pi n}{t} = \frac{2\pi \times 60}{60} = 2\pi\ rad\ s^{-1};$$

$I = 0.1 kg\ m^2; \tau = 0.03 Nm.$

Work done = $\frac{1}{2} I\left(\omega_f^2 - \omega_i^2\right)$

$\tau\theta = \frac{1}{2} I\left(\omega_f^2 - \omega_i^2\right)$ or

$$\theta = \frac{1}{2}\left(\frac{I}{\tau}\right)\left(\omega_f^2 - \omega_i^2\right) = \frac{0.1}{2 \times 0.03}\left((2\pi)^2 - \pi^2\right) = \frac{10}{2 \times 3} \times 3\pi^2 = 5\pi^2.$$

Number of revolutions, $n = \frac{\theta}{2\pi} = \frac{5\pi^2}{2\pi} = \frac{5\pi}{2} = 7.855\, rev.$

**6. A fly wheel in the form of a disc is initially at rest. When a constant torque acts on it for 1 minute, it attains a speed of 600 rpm. Calculate the torque, it mass and radius of the disc are 10 kg and 0.4m respectively.**

Sol : M = 10 kg; R = 0.4 m ;

MI of a circular disc about a transverse axis $= \frac{MR^2}{2} = 10\frac{(0.4)^2}{2} = 0.8\, kg\ m^2.$

$\omega_i = 0; \omega_f = \frac{2\pi n}{t} = \frac{2\pi(600)}{60} = 20\pi\ rad\ s^{-1}$ and t = 1 minute = 60 s.

$$\alpha = \frac{\omega_f - \omega_i}{t} = \frac{20\pi - 0}{60} = \frac{\pi}{3} rad\ s^{-1}.$$

The torque, $\tau = I\alpha = 0.8\left(\frac{\pi}{3}\right) = 0.8379 N\ m.$

**7. The angular momentum of a body changes by 80 $kg\ m^2 s^{-1}$ when its angular velocity changes from 20 $rad\ s^{-1}$ to 40 $rad\ s^{-1}$ . Find the change in its kinetic energy of rotation.**

Sol : **Let I be the M.I of the body**

$L_1 = I \times 20$ and $L_2 = I \times 40$

Change in angular momentum = $L_2 - L_1 = 20\ I$

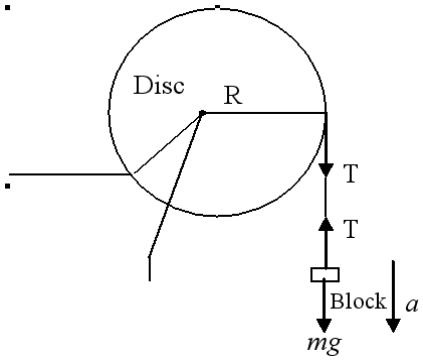
Given that, $20\ I = 80$ or $I = 4$ Kg-m$^2$

$\omega_1 = 10$ rad $s^{-1}$ and $\omega_2 = 30$ rad $s^{-1}$

Change in K.E $= \frac{1}{2}I\omega_2^2 - \frac{1}{2}I\omega_1^2 = \frac{1}{2}I\left(\omega_2^2 - \omega_1^2\right) = \frac{1}{2}\times 4\times\left(40^2 - 20^2\right) = 2400\,J$

**8. A mass less string is wrapped around a disc that has a radius of 10 cm and mass of 1.500 kg. The free end of the string is attached to a hanging block of mass 1.000 kg; the other end is fixed to a point on the rim of the disk. Neglecting friction, find (a) the linear acceleration of the hanging block if the block is released from rest and (b) the force exerted by the bearing on the pulley.** $\left(g = 10\,ms^{-2}.\right)$

Sol : Let M and m be the masses of the disc and block respectively. R is the radius of the disc. Linear acceleration of the block is a. The forces on the block are i) Gravitational force, mg and ii) the tension T




$ma = mg - T$

Also, Torque on the disc, $\tau = T \times R$

$$I\alpha = TR \Rightarrow \frac{MR^2}{2}\alpha = TR$$

$$\frac{MR^2}{2}\frac{a}{R} = TR \quad \left(\because a = r\alpha \text{ and } r = R\right)$$

$$T = \frac{Ma}{2}.$$

$$\therefore ma = mg - \frac{Ma}{2} \Rightarrow ma + \frac{Ma}{2} = mg \Rightarrow a\left(m + \frac{M}{2}\right) = mg \Rightarrow a = \frac{mg}{\left(m + \frac{M}{2}\right)}$$

Now, m = 1kg; M = 1.5 kg; and $g = 10\,ms^{-2}$.

$$\therefore a = \frac{1(10)}{\left(1 + \frac{1.5}{2}\right)} = \frac{10}{1.75} = 5.714\,m\,s^{-2}.$$

**9. If the radius of the earth is suddenly halved keeping its mass constant find its time period of rotation around its own axis.**

Sol: From the law of conservation angular momentum,

$$I_1\omega_2 = I_2\omega_2. \text{ Or } \frac{2}{5}MR_1^2\ \frac{2\pi}{T_1} = \frac{2}{5}MR_2^2\ \frac{2\pi}{T_2}$$

$$\frac{R_1^{\ 2}}{T_1} = \frac{R_2^{\ 2}}{T_2} \Rightarrow \frac{R^2}{24} = \frac{R^{\ 2}}{4\times T_2} \Rightarrow T_2 = 6\,hour$$

**10. A ballet dancer spins about a vertical axis at 60 rpm with arms outstretched. With her arms folded the angular frequency increases to 90 rpm. Find the change in her moment of inertia.**

Sol : From the law of conservation of angular momentum,

$I_1\omega_2 = I_2\omega_2. \Rightarrow I \times 60 = I_2 \times 90$

Final moment of inertia, $I_2 = \frac{2I}{3}$.

Change in moment of inertia = Initial $I$ − Final $I$

$\Delta I = I - \frac{2I}{3} = \frac{I}{3}$

% change in moment of inertia = $\frac{\Delta I}{I} = \frac{100}{3}\% = 33\frac{1}{3}\%$.

**11. A horizontal disc is freely rotating about a vertical axis passing through its center at the rate of 100 rpm. A blob of wax of mass 20 g falls on the disc and sticks to it at a distance of 5 cm from the axis. If the moment of inertia of the disc about the given axis is $2\times10^{-4} kg\,m^2$, find the new frequency of rotation of the disc.**

Sol: $I_1 =$ Moment of inertia of the disc = $2\times10^{-4} kg\,m^2$.

$I_2 =$ Moment of inertia of the disc + Moment of inertia of the blob of wax on the disc

$= 2\times10^{-4} + mr^2 = 2\times10^{-4} + 20\times10^{-3}\left(0.05\right)^2 = 2.5\times10^{-4} kg\,m^2$

From the law of conservation of angular momentum,

$I_1\omega_1 = I_2\omega_2 \Rightarrow 2\times10^{-4}\times100 = 2.5\times10^{-4}\omega_2 \Rightarrow \omega_2 = \frac{100\times2}{2.5} = 80\,rpm.$

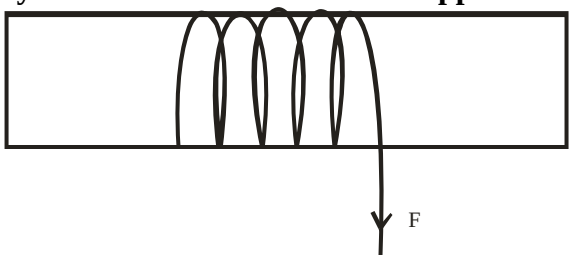
## Exercise 2

**1. The angular momentum of rotating body is increased by 20%. What will be the increase in its rotation kinetic energy?**

**A.** $E = \frac{L^2}{2I}$ *or* $\frac{E_2}{E_1} = \frac{{L_2}^2}{{L_1}^2} = \left(\frac{120}{100}\right)^2 = 1.44$ or $\frac{E_2 - E_1}{E_1}\times100 = 44\%$

**2. A mass less string is wrapped around a uniform solid cylinder of mass 30 kg and radius 0.20 m One end of the string is attached to the cylinder and the free end is pulled tangentially by a force that maintains a constant tension of 3.0 N. Find (a) the angular acceleration and b) the angular speed of the cylinder 2.0 s after the force is applied to the cylinder at rest.**

**A.**




M = 30 Kg, r = 0.2 m, F = 3 N

$\tau = rF = I\alpha$ ; I = $\frac{mr^2}{2} = 0.6$

a) $\alpha = \frac{rF}{I} = \frac{0.2\times3}{0.6} = 1$ rad $s^{-2}$

b) $\omega_0 = 0$, $\omega = \omega$ , t = 2s, $\alpha$ = 1 rad $s^{-2}$

= $\omega$ + t = 0 + (1×2) = 2 rad $s^{-1}$

**3. The angular momentum of a body changes by 60 kg $m^2$ $S^{-1}$ when its angular velocity changes from 10 rad $S^{-1}$ to 30 rad $S^{-1}$. Find the change in its kinetic energy of rotation.**

**A.** Let I be the M.I of the body

$L_1$ = I 10 and $L_2$ = I 30

Change in angular momentum = $L_2 - L_1$ = 20 I

Given that 20 I = 60 or I = 3 Kg-$m^2$

$\omega_1 = 10$ rad $s^{-1}$ and $\omega_2 = 30$ rad $s^{-1}$

Change in K.E $= \frac{1}{2}I\omega_2^2 - \frac{1}{2}I\omega_1^2$

$$= \frac{1}{2}I\left(\omega_2^2 - \omega_1^2\right) = \frac{1}{2}\times 3\times\left(30^2 - 10^2\right) = 1200\ J$$

**4. A door of moment of inertia 4 kg $m^2$ is at rest. When a torque of Nm acts on it find its angular acceleration. Find also its angular velocity after 1 S.**

**A.** I = 4 Kg-$m^2$, $\tau = 2\ \pi$ Nm t = I s or and $\alpha = \frac{\tau}{I} = \frac{2\pi}{4} = \frac{\pi}{2} = \frac{3.142}{2} = 1.571$ rad $s^{-2}$

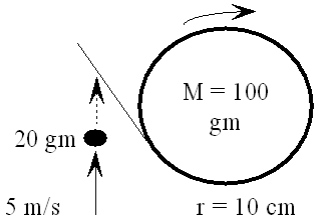
Let ω be the angular velocity after 1 s

$$\omega_0 = 0, \omega = \omega, \alpha = \frac{\pi}{2}, t = 1s$$

$$\omega = \omega_0 + \alpha t \ or\ \omega = \frac{\pi}{2}\times 1 = \frac{\pi}{2} rad \quad or\ \omega = 1.571\ rad\ s^{-1}$$

**5. A disc of mass 100 g and radius 10 cm has a projection on its circumference. The mass of the projection is negligible. A 20 g bit of putty with a velocity of 5 m $S^{-1}$strikes the projection and sticks fast. Find the angular velocity given to the disc.**

**A.**




mvr = I ω

m = $\frac{200}{1000}$ Kg, $v$ = 5 $ms^{-1}$, r = 0.1 m

$$I = \frac{Mr^2}{2} + mr^2 = \frac{100}{1000}\times\frac{1}{10}\times\frac{1}{10}\times\frac{1}{2} + \frac{20}{1000}\times\frac{1}{10^2}$$

$$= 0.5\times10^{-3} + 0.2\times10^{-3} = 7\times10^{-4}$$

$$\frac{20}{1000}\times 5\times\frac{1}{10}=\frac{7}{1000}\times\omega \qquad \text{or} \qquad \omega=\frac{100}{7}=14.29 \text{ rad s}^{-1}$$

**6. A ballet dancer spins about a vertical axis at 120 rpm with arms outstretched. With her arms folded, moment of inertia about the axis of rotation decreases by 40%. Calculate the new rate of rotation.**

**A.** Let $I_1$ = 100 then $I_2$ = 60

$\omega_1$ = 120 rpm; $\omega_2$ = ?

$I_1\omega_1 = I_2\omega_2 \Rightarrow 100 \text{ x } 120 = 60 \text{ x } \omega_2$ or $\omega_2$ = 200 rpm

**7. A wheel is rotating with a speed of 500 rpm on a shaft. Second identical wheel initially at rest is suddenly coupled on the same shaft. What is the speed of the resultant combination? Assume that the moment of inertia of the shaft is negligible.**

**A.** Let I be the M.I of the wheel

$I_1$ = I, $\omega_1$ = 500 rpm

$I_2$ = I + I = 2I, $_2$ = ?

$I_{11} = I_2\ \omega_2$ or I x 500 = 2I x $\omega_2$ Or $\omega_2$ = 250 rpm

**8. The moment of inertia of a fly wheel making 300 revolutions per minute is 0.3 kgm$^2$, find torque required to bring it to rest in 20 s.**

**A.** I = 0.3 Kg-m$^2$, n = 300/60 = 5 rev/s

$\omega_0$ = 2n = 2 x 5 = 10 rad/s

$\omega=\omega_0+\alpha t$ or $0 = 10\pi + 20\ \alpha$

Or $\alpha$ = – 10/20 = – $\pi$/2 rad s$^{-2}$

$\tau = I\alpha$ = 0.3 x $\pi$/2 = 0.3 x $\frac{22}{7}\times\frac{1}{2}$ = 3.3 / 7 = 0.471 Nm

**9. A circular metal disc of mass 200 g and radius 20 cm makes 10 revolutions per second about an axis passing through the centre and perpendicular to its plane. Find a) moment of inertia about that axis. b) Torque required to change its angular velocity from 10 rps to 20 rps in 5 s.**

**A.** m = 200g = 0.2 Kg, r = 20 cm = 0.2 m, $\omega$ = 2 $\pi$ x 10 = 20$\pi$ rad s$^{-1}$

a) M.I of the disc $I=\frac{mr^2}{2}=\frac{0.2\times0.2\times0.2}{2}=4\times10^{-3}kg-m^2$

b) $\omega_0$ = 10 x 2$\pi$ = 20 rad s$^{-1}$ ; = 20 x 2$\pi$ = 40$\pi$ rad s$^{-1}$ and t = 5 s

$\omega=\omega_0+\alpha t$ or $40\pi = 20\ \pi + 5\alpha$

Or $\alpha$ = 4$\pi$ rad s$^{-2}$

But , $\tau = I\alpha$ = 4 x 10$^{-3}$ x 4$\pi$ = 16$\pi$ x 10$^{-3}$ Nm $\cong$ 0.05 Nm

**10. When 100 J of work is done on a fly wheel, its angular velocity is increased from 60 rpm to 180 rpm. What is the moment of inertia of the wheel ?**

**A.** W = 100 J, $\omega_1$ = 60 rpm = 2$\pi$ rad s$^{-1}$

$\omega_2$ = 180 rpm = 6$\pi$ rad s$^{-1}$

Work done = change in rotational K.E

$$100 = \frac{1}{2} I\left(\omega_2{}^2 - \omega_1{}^2\right) = \frac{1}{2} I\left(36\pi^2 - 4\pi^2\right) \quad \text{Or} \quad I = \frac{200}{32\pi^2} = \frac{5}{8} = 0.63 \text{ Kg-m}^2$$

**11. A metal piece of mass 120 g is stretched to form a plane, rectangular sheet of area of cross section 0.54 $m^2$. If length and breadth of this sheet are in the ratio 1 : 6, find its moment of inertia about an axis passing through its centre and perpendicular to its plane.**

**A.** Let *l* m be the length of the sheet

Breadth of the sheet b = 6 *l m*

Area = *l* x 6*l* = 6 $l^2$ = 0.54

*l* = 0.3 m, b = 1.8 m

Mass of the sheet M = 120 g = 0.12 Kg

M.I of the sheet $I = \frac{M\left(l^2 + b^2\right)}{12} = \frac{0.12\left(0.3^2 + 1.8^2\right)}{12} = \frac{0.12 \times 3.33}{12} = 3.33 \times 10^{-2} kg - m^3$

## ASSESS YOURSELF

**1) Is it possible to open a door by applying a large force at a point which is very close to the hinges?**

A) No, because the distance of point of application of force from the axis of rotation is very small and hence the moment of force is very small.

**From $\tau = r\alpha$, r is very less and hence $\tau$ is also very less.**

**2) What will be the condition for the equilibrium of a rotating body under the action of coplanar parallel forces?**

A) Algebraic sum of the moments of the forces about any point in its plane is to be zero (or)

Sum of the clock wise moments of force must be equal to the sum of the anti-clock wise moments of forces about a point in the plane of rotating body.

**3) What happens to the duration of day when polar ice cap melts?**

A) Increases. When the polar ice cap melts, according to the law of conservation of angular momentum, moment of inertia of the earth increases and the angular velocity of the rotation of the earth decreases $\left(T = \frac{2\pi}{\omega}\right)$ Hence T increases..

**4) What is the direction of the angular momentum of a projectile in x-y plane?**

A) Along z-axis.

**5) A person is initially standing on a rotating turn table. If the person sits at the same place how does its moment of inertia and angular momentum change?**

A) If the person sits at the same place, both moment of inertia and angular momentum do not change.

**6) If a rigid body has both tranlatory and rotatory motions, the motion of the body is called rolling motion. What will be the kinetic energy of such a a body?**

A) Kinetic energy of a rolling body = KE of translatory motion + KEof rotatory motion .

$$\text{Total KE} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$