CHAPTER NO. 5 (CIRCULAR MOTION)

Question 5.1:- Explain the difference between tangential velocity and the angular velocity. If one of these is given for a wheel of known radius, how will you find the other?

Answer:-

The linear velocity of an object moving along a curve or circular track is directed along the tangent at any point to the curve and is called tangential velocity. It is denoted by v_t. Its unit is m s^{-1}. For a wheel of known radius, it is determined by the formula $v_t = r\omega$.	The rate of change of angular displacement of an object with respect to time moving across the circular path is called angular velocity. It is denoted by ω. Its unit is rad s^{-1}. For a wheel of known radius, it is determined by the formula $\omega = v_t/r$.

Question 5.2:- Explain what is meant by centripetal force and why it must be furnished to an object if the object is to follow a circular path?

Answer:- The force which is needed to bend the normal straight path of an object into circular trajectory is called centripetal force. It is denoted by F_c. Mathematically, $F_c = mv^2/r$.

In order to move an object in a circular path, its direction needs to be changed at every point. To change the direction of motion continuously, a perpendicular force needs to be applied. This force is known as centripetal force and is directed along the radius towards the centre of the circle. In the absence of centripetal force, object will move along the straight path making tangent with the circular trajectory.

Question 5.3:- What is meant by moment of inertia? Explain its significance.

Answer:- The intrinsic property of an object to resist any change in its state of uniform circular motion is called moment of inertia. It depends upon mass and distribution of mass with respect to chosen axis of rotation.

For a rigid body, moment of inertia is calculated as $I = \sum_{i=1}^{n} m_i r_i^2$.

Moment of inertia plays the same role in angular motion as the mass plays in translational motion. It is the rotational analogue of mass in rotational motion.

Question 5.4:- What is meant by angular momentum? Explain the law of conservation of angular momentum.

Answer:- The cross or vector product of position vector and linear momentum is called angular momentum. Mathematically, $\vec{L} = \vec{r}\ x\ \vec{P}$. It is a similar quantity to linear momentum and can also be expressed as product of moment of inertia and angular velocity.

The law of conservation of angular momentum states that total angular momentum of a system remains constant provided no external torques acts on the system. Mathematically, $I_1\omega_1 = I_2\omega_2$.

Question 5.5:- Show that orbital angular momentum L_o = mvr.

Answer:- We know that $\vec{L} = \vec{r}\ x\ \vec{P}$. Its magnitude is given by L = rP sin θ.

For circular/orbital motion, $L = L_o$, P = mv and $\theta = 90^o$.

$L_o = r(mv) \sin 90^o = mvr$.

Question 5.6:- Describe what should be the minimum velocity, for a satellite, to orbit close to the Earth around it.

Answer:- In order to put a satellite in an orbit close to the earth, the necessary centripetal force is provided by gravitational force of attraction between earth and satellite.

$F_c = mg$

Since r = R = Radius of earth, we can say that $mv^2/R = mg$ and $v = \sqrt{gR} = \sqrt{9.8\ x\ 6.4\ x\ 10^6}$

$v = 7.9 \times 10^3\ m\ s^{-1} = 7.9\ km\ s^{-1}$.

This is the minimum velocity to put a satellite into orbit around the Earth.

Question 5.7:- State the directions of the following vectors in simple situations; angular momentum and angular velocity.

Answer:- According to the relation $\vec{L} = \vec{r}\ x\ \vec{P}$, the angular momentum is directed in a direction perpendicular to the plane containing the radius of circular path and momentum of the object i.e. along the axis of rotation.

The direction of angular velocity is also taken along the axis of rotation for counter clockwise rotation by using right hand rule.

Question 5.8:- Explain why an object, orbiting the Earth, is said to be freely falling. Use your explanation to point out why objects appear weightless under certain circumstances.

Answer:- Any object which is orbiting around the earth is accelerated towards the centre of the earth with an acceleration equal to the acceleration due to gravity g and is considered as freely falling object.

When any object is accelerated towards the earth, its apparent weight is T = mg – ma.

For a freely falling object, a = g so T = mg – mg = 0.

Therefore, all freely falling objects including the satellites orbiting the earth appear weightless.

Question 5.9:- When mud flies off the tyre of a moving bicycle, in what direction does it fly? Explain.

Answer:- The mud flies off the tyres of a moving bicycle, it flies in a direction making tangent to the tyre.

When speed of the tyre increases, the required centripetal force increases and adhesive force between tyres and mud is not enough to keep the mud stick with the tyre. Thus, it flies off the tyre in a direction making tangent to the tyre.

Question 5.10:- A disc and a hoop start moving down from the top of an inclined plane at the same time. Which one will be moving faster on reaching the bottom?

Answer:- When a disc and hoop start moving down from top of an inclined plane at height h,

DISC	HOOP
Potential energy at top = Translational K.E. + Rotational K.E. mgh = $\frac{1}{2}$ m v^2 + $\frac{1}{2}$ I ω^2 For a disc, I = $\frac{1}{2}$ m r^2 mgh = $\frac{1}{2}$ m v^2 + $\frac{1}{2}\frac{1}{2}$ m r^{2}ω^2 = $\frac{3}{4}$ m v^2 v = $\sqrt{\frac{4gh}{3}}$	Potential energy at top = Translational K.E. + Rotational K.E. mgh = $\frac{1}{2}$ m v^2 + $\frac{1}{2}$ I ω^2 For a disc, I = m r^2 mgh = $\frac{1}{2}$ m v^2 + $\frac{1}{2}$ m r^{2}ω^2 = m v^2 v = $\sqrt{gh}$

The disc moves faster when reaches at bottom of the inclined plane.

Question 5.11:- Why does a diver change his body positions before and after diving in the pool?

Answer:- The diver obeys law of conservation of angular momentum according to following relation $I_1\omega_1 = I_2\omega_2$.

When diver is about to jump from the diving board, his arms and legs are fully stretched having a large moment of inertia and small angular velocity. After jumping from the board, he closes his body in a closed tuck position reducing moment of inertia and increasing the spinning velocity.

A diver changes his body position after diving in the pool in order to cover some extra somersaults.

Question 5.12:- A student holds two dumb-bells with stretched arms while sitting on a turn table. He is given a push until he is rotating at certain angular velocity. The student then pulls the dumb-bells towards his chest. What will be the effect on rate of rotation?

Answer:- According to the law of conservation of angular momentum, $I_1\omega_1 = I_2\omega_2$.

When arms of the students are stretched, its moment of inertia is large and angular velocity is small.

When he pulls the dumb-bells towards his chest, his moment of inertia decreases and hence angular velocity increases to keep the angular momentum constant.

Question 5.13:- Explain how many minimum number of geo-stationary satellites are required for global coverage of TV transmission.

Answer:- A geo-stationary satellite covers 120^o of longitude, so the whole of the Earth's surface for global transmission can be covered by three correctly positioned geo-stationary satellites i.e. $120^o \times 3 = 360^o$.