Chapter # 05 (Circular Motion)
Important Short Questions

1. Define angular displacement. And write its unit.

Ans: "The angle subtended at the center of a circle by a body moving along the circumference in a given time is called angular displacement. It is denoted by $\Delta\theta$"
Unit: Its S.I unit is radian.

2. State right hand rule to find the direction of angular displacement.

Ans: Right hand rule:

Grasp the axis of rotation in right hand with fingers curling in the direction of rotation then the erect thumb indicates the direction of angular displacement.

3. What is the difference between a degree and radian?

Ans:

Degree	Radian
• The unit of measurement which is used to measure in plane angles is called degree. • $\mathbf{1^o = \frac{\pi}{180}}$	• A unit of measurement which is used to measure angles is called radian. • A radian is equal to 180^o. • **π radian = 180^o**

4. Prove that $S = r\theta$

Ans: Proof:

Consider a body moving in a circle of radius "r". After a small interval of time, it moves from A to B. If "O" is the center of the circle, then $\angle AOB = \theta$ is called angular displacement.

$$\text{Angular displacement} = \frac{\text{arc length}}{\text{radius}}$$

$$\theta = \frac{\widehat{AB}}{r}$$

$$\theta = \frac{S}{r}$$

$$\mathbf{S = r\theta}$$

5. Define angular velocity (angular frequency). Give its formula and unit. How can we find the direction of angular velocity?

Ans: Angular velocity:

"The time rate of change of angular displacement is called angular velocity"

$$\boldsymbol{\omega = \frac{\Delta\theta}{\Delta t}}$$

Unit: Its S.I unit is $rads^{-1}$.
Direction:

It is a vector quantity. Its direction is along the axis of rotation and can be determined by right hand rule.

Right hand rule:

Grasp the axis of rotation in right hand with fingers curling in the direction of rotation then the erect thumb indicates the direction of angular velocity.

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6. Define angular acceleration and instantaneous acceleration. Write its formula and unit.

Ans: Angular Acceleration:

"The time rate of change of angular velocity is called angular acceleration"

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

Instantaneous Acceleration:

"The limiting value of $\Delta\theta/\Delta t$ as the time interval Δt. Following the time t, approaches to zero is called instantaneous acceleration"

$$\alpha_{ins} = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t}$$

Unit: Its S.I unit is $rads^{-2}$.

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7. Define positive angular acceleration and negative angular acceleration.

Ans: Positive Angular Acceleration:

"When a body covers angular displacement $\Delta\theta$ in counter clock wise direction then acceleration is produced in this body called positive angular acceleration"

Negative Angular Acceleration:

"When a body covers angular displacement $\Delta\theta$ in clock wise direction then acceleration is produced in this body called negative angular acceleration"

$$\alpha_{ins} = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t}$$

Unit: Its S.I unit is $rads^{-2}$.

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8. Drive the relation between linear velocity and angular velocity. OR Prove that $v = r\omega$

Ans: Proof:

As we know that

$$S = r\theta$$
$$\Delta S = r\Delta\theta$$

Dividing both side by time

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

Now applying limit on both sides.

$$\lim_{\Delta t \to 0} \frac{\Delta S}{\Delta t} = \lim_{\Delta t \to 0} r\frac{\Delta\theta}{\Delta t}$$
$$\lim_{\Delta t \to 0} \frac{\Delta S}{\Delta t} = r\left(\lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}\right)$$

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

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9. Drive the relation between linear acceleration and angular acceleration. OR Prove that $a = r\alpha$

Ans: Proof:

As we know that

$$v = r\omega$$

$$\Delta v = R\omega$$

Dividing both side by time

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

Now applying limit on both sides.

$$\underset{\Delta t \to 0}{\text{Lim}} \frac{\Delta v}{\Delta t} = \underset{\Delta t \to 0}{\text{Lim}}\, r\frac{\Delta \omega}{\Delta t}$$

$$\underset{\Delta t \to 0}{\text{Lim}} \frac{\Delta v}{\Delta t} = r\left(\underset{\Delta t \to 0}{\text{Lim}} \frac{\Delta \omega}{\Delta t}\right)$$

$$\mathbf{a = r\alpha}$$

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10. Define centripetal acceleration and centripetal force.

Ans: Centripetal Acceleration:

"The instantaneous acceleration of an object travelling with uniform speed in a circle is directed towards the center of the circle is called centripetal acceleration"

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

Centripetal Force:

"The force which compels a body to move in a circular path is called centripetal force"

OR

"The force which bends the normally straight path of a particle intro circular path is called centripetal force"

$$\mathbf{F_c = \frac{mv^2}{r}}$$

Examples:

- Force acting on electrons in fixed orbits around the nucleus.
- Force acting on earth around the sun

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11. Define moment of inertia. How it is related to torque.

Ans: Moment of Inertia:

"The moment of inertia of a particle is defined as the product of mass and the square of its perpendicular distance from axis of rotation."

Mathematically,

$$I = mr^2$$

How it is related to torque?

$$F = ma$$

$$F = m(r\alpha) \qquad \text{As } a = r\alpha$$

Multiply both sides of "r"

$$rF = mr(r\alpha)$$

$$rF = mr^2 \alpha$$
$$\boldsymbol{\tau = I\alpha}$$

12. Give practical uses of rotational K.E by fly wheels.

Ans: Uses of rotational K.E:

Practically, rotational K.E is used by fly wheels, which are essential parts of many engines. A fly wheel stores energy between the power strokes of pistons. So, that energy is uniformly distributed over the full revolution of the crank shaft and hence, the rotation remains smooth.

13. What is difference between real and apparent weight?

Ans:

Real Weight	Apparent Weight
• The gravitational pull of the Earth on the body is called real weight. • It depends upon mass and gravitational acceleration. • Its formula is W = mg	• The reading of the spring balance when the object is accelerating up or down is called apparent weight. • It depends upon the acceleration of upward or downward moving objects. • Its formulae are **Increase in Weight:** T = w + ma **decrease in Weight** T = w - ma

14. What is artificial gravity? Write down expression for its frequency.

Ans: Artificial Gravity:

"The gravity like effect produced in an orbiting satellite by spinning it around its own axis is called artificial satellite"

Expression for frequency:

For the creation of artificial gravity, the artificial satellite set into rotation with a particular frequency around own axis.

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{R}}$$

15. Define geostationary satellites. And write down its uses.

Ans: Geostationary Satellites:

"The satellite which completes its one revolution around Earth in 24 hours is called geo-stationary satellites"

Uses of Geostationary Satellites:

There are a lot of applications of geostationary satellites. Some of them are following.

- Weather forecasting
- GPS navigation
- Military purposes
- Telecommunication

16. What is meant by INTELSAT? AT what frequencies the, INTELSAT – IV operates?

Ans: INTELSAT means international telecommunication satellite organization. It is managed by 126 countries. It works at the microwave frequencies of 4,6,11 and 14 GHz and has the capacity of 30,000 two-way telephone circuit plus three T.V channels.

17. What is the main difference between Newton's and Einstein view of gravitation?

Ans:

Newton's view of gravitation	Einstein's view of gravitation
• According to Newton's theory, the gravitation is the intrinsic property of matter that every particle of matter every other particle with a force that is directly proportional to the product of their masses and is inversely proportional to the square of distance between them. • Gravitation is due to force between them.	• According to Einstein's view of gravitation, gravity is due to the curvature of space and time caused by masses. • In Einstein's view, we don't speak about gravity acting on bodies, but we say that bodies and light rays move along geodesics in curved space.

Exercise Short Questions

1. Explain the difference between tangential velocity and the angular velocity, if one of these given for a wheel of known radius, how will you find the other?

Ans:

Tangential Velocity	Angular Velocity
• Velocity of a body along the tangent is known as tangential velocity. • Its unit is ms^{-1}. • Its direction is along the tangent. $v_t = \frac{\Delta \vec{d}}{\Delta t}$, $v = r\omega$	• The rate of change of angular displacement is called angular velocity. • Its unit is $rads^{-1}$. • Its direction is along the axis of rotation. $\vec{\omega} = \frac{\Delta \vec{\theta}}{\Delta t}$, $\omega = \frac{v}{r}$

If one of the them is given for a wheel of known radius, then the other can be calculated using the relation $v = r\omega$

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?

Ans: The force which bends the normally straight path into circular path is called centripetal force.

OR

The force which compels a body to move along a circular path is called centripetal force.

Mathematically,

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

Significance:

It is perpendicular to the tangential velocity and directed towards the centre of the circular path. Without centripetal force body will move along the tangent.

3. What is meant by moment of inertia? Explain its significance.

Ans: The moment of inertia of a particle is defined as the product of mass and the square of its perpendicular distance from axis of rotation.

Mathematically,

$$I = mr^2$$

Physical meaning:

The moment of inertia plays same role during angular motion which plays mass during linear motion. Mass is the measure of linear inertia while moment of inertia measures of rotational inertia of a body. Moment of inertia determine the angular acceleration while mass determine the linear acceleration.

4. What is meant by angular momentum? Explain the law of conservation of angular momentum?

Ans: The product of moment of inertia and angular velocity of a rotating body is called angular momentum. It is denoted by $\vec{L}$. Mathematically,

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

$$\vec{L} = r\, p \sin\theta$$

$$\vec{L} = m\, v\, r \sin\theta$$

Law of conservation of momentum:

The total angular momentum of the system remains constant, when no external torque acts on it.

Mathematically,

$$L_{total} = L_1 + L_2 + L_3 + \ldots\ldots\ldots = I\omega = \text{Constant}$$

5. Show that orbital angular momentum $L_o = mvr$

Ans: Proof:

Consider particle of mass m moving in a circle of radius r as shown in figure.

As

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

$$L_o = r\, p \sin\theta$$

Where θ is the angle between **r** and **P**.

$$L_o = r\,(mv) \sin\theta \qquad (P = mv)$$

$$L_o = m\, v\, r \sin\theta$$

As the angle between **r** and **P** is 90º.

$$L_o = m\, v\, r \sin 90$$

$$L_o = m\, v\, r\, (1)$$

$$L_o = m\, v\, r$$

Hence, it is proved.

6. Describe what should be the minimum velocity, for a satellite, to orbit close to the earth around it.

Ans: Critical Velocity:

The minimum velocity needed to orbit a satellite close to the earth is called critical velocity.

Calculation:

Consider a satellite of mass m is moving with velocity v in a circle of radius R (radius of the earth). Since, gravitational force provides the necessary centripetal force.

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

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

$$v^2 = gR$$

So,

$$v = \sqrt{gR}$$

$$v = \sqrt{9.8 \times 6.4 \times 10^6}$$

$$v = 7900\ ms^{-1}$$

$$v = 7.9\ kms^{-1}$$

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7. State the direction of the following vectors in simple situation; angular momentum and angular velocity.

Ans: The direction of angular momentum and angular velocity is determined by right hand rule.

For Angular Momentum:

We know that $\vec{L} = \vec{r} \times \vec{P}$

This shows that the direction of angular momentum is perpendicular to the plane containing $\vec{r}$ and $\vec{P}$. In case of circular motion, angular momentum is perpendicular to the plane of circle and is along axis of rotation.

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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.

Ans: Explanation:

When the object is thrown horizontally fast enough from a certain height, so that the curvature of its path will match with the curvature of earth then the object simply revolves round the Earth. Now, the motion of the object is under the constant acceleration due to gravity (equal to centripetal acceleration). Hence, we can say the orbiting body is freely falling body.

Weightlessness of the body:

A freely falling body moves only under the action of gravitational force so that the object is said to be in state of weightlessness.

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

Ans: The mud flies off along the tangent to the tyre.

Reason:

When speed of bicycle increases then adhesive force (Sticking force) between the mud and the tyre is not sufficient to provide the necessary centripetal force so that mud leaves the tyre and moves along tangent to tyre.

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?

Ans: Disc will be moving faster on reaching the ground.

Proof:

Speed of hoop at the bottom of inclined plane is,

$$v_{hoop} = \sqrt{gh}$$

Speed of the disc moving down the inclined plane is,

$$v_{disc} = \sqrt{\frac{4}{3}gh} = \sqrt{\frac{4}{3}} \times \sqrt{gh}$$

$$v_{disc} = 1.15 v_{hoop}$$

$$v_{disc} > v_{hoop}$$

11. Why does a diver change its positions before and after diving in the pool?

Ans: The diver changes his body to make extra somersaults.

Explanation:

When a diver lifts off from the living board, his legs and arms are full extended. In this case his moment of inertia is large (I_1) but angular velocity (ω_1) is small.

When the legs and arms of the diver are drawn into the closed tuck position, its moment of inertia is reduced considerably so that its angular velocity will increase to conserve the angular momentum.

$$I_1\omega_1 = I_2\omega_2$$

12. A student holds two dump-bells 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?

Ans: Rate of rotation increases when student pulls the dumb-bells towards its chest.

Reason:

When the student pulls the dumb-bells towards its chest, his moment of inertia decreases and to conserve angular momentum, his angular velocity increases and he spins faster.

13. Explain how many minimum number of geo-stationary satellites are required for global coverage of T.V transmission.

Ans: Minimum three correctly positioned geo-stationary satellites are required for the global coverage of T.V transmission.

Explanation:

As each satellite in geo-stationary orbit covers 120° of longitude so that whole populated Earth's surface can be covered by three correctly positioned geo-stationary satellites.

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