

Chapter	3 Circular and Rotational Motion	Class	1 st Year	Subject	Physics
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Give Short Answers of the Following Questions

1. Prove that 1 radian = 57.3°

Ans. As $S = r\theta$

$$\text{Or } \theta = \frac{S}{r} \text{ (rad)}$$

In one complete rotation, the distance covered 'S' is equal to the circumference of circle i.e. '2πr'.

$$\text{So } \theta = \frac{2\pi r}{r}$$

$$\theta = 2\pi \text{ (radian)}$$

As we know that 1 revolution = 2π radian = 360°

$$1 \text{ radian} = \frac{360^\circ}{2\pi}$$

$$1 \text{ radian} = \frac{360^\circ}{2 \times 3.14}$$

$$1 \text{ radian} = 57.3^\circ$$

2. Prove that $v = r\omega$.

Ans. As $S = r\theta$

For small changes

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

Dividing both sides by 'Δt'

$$\text{So, } \frac{\Delta S}{\Delta t} = r \frac{\Delta\theta}{\Delta t}$$

Applying limit $\Delta t \rightarrow 0$

$$\lim_{\Delta t \rightarrow 0} \frac{\Delta S}{\Delta t} = \lim_{\Delta t \rightarrow 0} r \frac{\Delta\theta}{\Delta t}$$

$$v = r\omega$$

In vector form, $\vec{v} = \vec{\omega} \times \vec{r}$.

3. Define centripetal force and centripetal acceleration. Also write their relations.

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

$$F_c = \frac{mv^2}{r} = mr\omega^2$$

The instantaneous acceleration of a body moving along a circle with uniform speed is always directed toward the center of circle is called centripetal acceleration.

$$A_c = \frac{v^2}{r} = r\omega^2$$

4. A loaf of bread is lying on the rotating plate. The crow takes the loaf of bread and the plate is rotating fast. Why?

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Ans. According to law of conservation of angular momentum the total angular momentum of a spinning body remains constant i.e.,

$$I_1\omega_1 = I_2\omega_2 \quad \because I = mr^2$$

$$m_1r^2\omega_1 = m_2r^2\omega_2 \quad \dots(1)$$

m_1 is mass of plate and bread and m_2 is only mass of plate when loaf of bread is taken away. i.e., m_2 , m_1 and r is constant. Therefore, in order to conserve the angular momentum when m_2 decreases then ω_2 increases i.e., angular velocity increases when loaf of bread is taken away.

5. Why the roads are made banked in hill stations?

Ans. In hill stations, the roads are made banked because only the frictional force is not enough to provide the necessary centripetal force to take the turn in fast speed. So by banking the road, components of the normal reaction become radial which provides the necessary centripetal force.

6. A ball tied to the end of the string, is swung in vertical loop under gravity. Find the value of tension at point A from figure?

Ans. As weight and the tension together give rise the centripetal force so we can write,

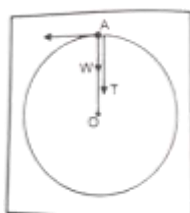
$$F_c = T + W$$

$$T = F_c - W$$

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

$$= m\left[\frac{v^2}{r} - g\right]$$

If $\frac{v^2}{r}$ is equal to g , then T will be zero and $F_c = W$.



7. State second law of motion in case of rotation.

Ans. Second law of motion in case of rotation: The second law of rotation motion in case of rotation states that the torque (τ) acting on a body is equal to the product of its moment of inertia (I) and its angular acceleration (α).

As $F = ma$

Multiplying both sides by r

$$rF = r(ma)$$

$$\tau = rm(r\alpha) \quad \because \tau = rF, a = r\alpha$$

$$\tau = I\alpha$$

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This is the rotational analogue of Newton's second law ($F = ma$).

8. What is the effect of changing the position of a diver while diving in the pool?

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

Explanation:

When a diver lifts off from the diving 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, his moment of inertia is reduced considerably so that his angular velocity will increase to conserve the angular momentum.

$$I_1\omega_1 = I_2\omega_2$$

9. How do we get butter from the milk?

Ans. Butter is obtained from milk by a process called centrifugation, in a machine called cream separator.

Explanation: In this machine, milk is whirled rapidly. Since milk is a mixture of light and heavy particles, when it is rotated, the light particles (cream) gather near the axis of rotation whereas the heavy particles (like skim milk) will go outward and hence cream can easily be separated from milk. The cream is then collected and further churned to separate butter.

10. Mass is a measure of inertia in linear motion. What is its analogue in rotational motion? Describe briefly.

Ans. Second law of motion can be expressed as,

For linear motion: $F = ma$

For angular motion: $\tau = I\alpha$

So torque is rotational analogy of force. Whereas mass is rotational analogy of moment of inertia. Just as mass resists changes in linear motion, moment of inertia resists changes in rotational motion. Moment of inertia depends on both the mass of the object and its distribution about the axis of rotation.

11. Why is it harder for a car to take turn at higher speed than at lower speed?

Ans. It is harder for a car to take turn at higher speed than at lower speed.

Reason: While turning a car requires centripetal force, given by

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

At higher speed, the term v^2 increases rapidly, so more force is required to maintain the turn. If the required frictional force is not available, the car may skid.

Hence, turning is harder at higher speeds due to increased centripetal force demand.

12. What are the benefits of using rare wheels of heavy vehicles consisted of double tires?

Ans. Heavy vehicles often uses double or multiple tires on rear wheels, having benefits.

(i) Increased contact area: More tyres increase the surface area in contact with the road, reducing pressure ($P = \frac{F}{A}$) on each tyre, which prevents sinking on soft surfaces.

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(ii) Improved load bearing: The load is shared among more tyres, reducing wear and tear and improving safety.

(iii) Better stability: Most important is that the multiple wheels provide greater stability, especially during turns and on uneven roads due to their large value of moment of inertia.

13. When a moving car turns around a corner to the left, in what direction do the occupants tend to fall? Explain briefly.

Ans. When a moving car turns left, the occupants tend to fall to the right.

Reason:

- When the car changes direction to the left, the bodies of the occupants continue moving in a straight line due to inertia (Newton's first law).
- Since the car is turning left and the bodies want to keep moving straight, they appear to move right relative to the car.

14. Why is the acceleration of a body moving uniformly in a circle, directed towards the centre?

Ans. The acceleration of a body moving uniformly in a circle is directed toward the centre.

Reason: In uniform circular motion, the direction of velocity changes continuously. Since velocity is vector, a change in its direction implies an acceleration.

This acceleration is called centripetal acceleration which is always points towards the centre of the circle, given by

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

This inward acceleration is necessary to keep the body moving along a circular path.

15. How does an astronaut feel weightlessness while orbiting from the Earth in a spaceship?

Ans. Reason:

- An astronaut feels weightlessness while orbiting, because both the astronaut and the spaceship are in the state of free fall towards the Earth under the influence of gravity.
- In orbit, the centripetal force required to keep the spaceship moving in a circular path is provided by gravity.
- Since both the spaceship and the astronaut inside are falling with same acceleration (i.e., $a = g$), there is no normal reaction force acting on the astronaut. Thus astronaut experiences apparent weightlessness.

16. If angular velocity of different particles of a rigid body is constant, will the linear velocity of these particles also constant?

Ans. No, the linear velocity of the particles will not be same, even if the angular velocity is constant.

The linear velocity 'v' of a particle is related to angular velocity ' ω ' by the relation

$$v = \omega r$$

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Where 'v' is the distance of the particle from the axis of rotation.

Since 'r' differs for different particles in a rigid body, their linear velocity (v) differ through all rotate with the same angular velocity (ω).

17. A loaf of bread is lying on rotating plate. A crow takes away the loaf of bread and the plates rotation increase. Why?

Ans. This happens due to the conservation of angular momentum.

Angular momentum (L) is given by

$$L = I\omega$$

Where I is the moment of inertia and ω is the angular velocity.

When the crow takes away the loaf, the total moment of inertia 1 (i.e., $I = mr^2$) of the system decreases.

Since no external torque acts, angular momentum is conserved. So, to keep L constant, ω must increase. Hence, the plate spins faster when the loaf is removed.

18. Why do we tumble when we take the sharp turn with large speed?

Ans. We tumble because of inertia and the need for centripetal force during a sharp turn.

When we move in a straight line, our body wants to continue in that line due to inertia (Newton's First law).

Taking a sharp turn requires a centripetal force ($F_c = \frac{mv^2}{r}$) to change the direction of our motion.

At large speed, if that force is insufficient, the body moves tangentially to the turn. We lose balance and tumble outward.

19. What will be time period of a simple pendulum in an artificial satellite?

Ans. The time period of a simple pendulum in an artificial satellite will be infinite.

Reason: In an artificial satellite, everything inside is in state of free fall due to its orbital motion. This creates a condition of weightlessness (i.e., $g_{\text{eff}} = 0$).

The time period of simple pendulum is

$$T = 2\pi \sqrt{\frac{L}{g}}$$

$$T = 2\pi \sqrt{\frac{L}{0}}$$

$$T = \infty$$

20. Is the motion of a satellite in its orbit, uniform or accelerated?

Ans. Yes, the motion of a satellite in a circular orbit is uniform in speed but accelerated in direction.

Reason: During the motion of a satellite in its orbit, magnitude of velocity (speed) remains constant, but direction continuously changes which causes centripetal acceleration ($a = \frac{v^2}{r}$).

Hence, motion is called uniform circular motion, which is type of accelerated motion due to the changing direction of velocity.

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21. What are the advantages that radian has been preferred as SI unit over degree?

Ans. Radian is preferred in SI units, because:

It is a pure ratio (arc length/radius), hence dimensionless, making it easier to use in mathematical equations. In rotational motion, these formation hold true only when angles are in radian:

$$V = r\omega \quad a = r\alpha$$

It aligns with calculus-base formulas like $\omega = \frac{\Delta\theta}{\Delta t}$, making it more natural for scientific analysis.

22. In uniform circular motion, what are the average velocity and average acceleration for one revolution? Explain.

Ans. Average velocity: In uniform circular motion, the average velocity for one revolution is zero. Average velocity is defined as:

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time}} = \frac{0}{t} = 0$$

As in one complete revolution, the displacement is zero, because the object reaches to its starting point.

The average angular velocity is

$$\text{Average velocity} = \frac{\text{Total angular displacement}}{\text{Total time}} = \frac{\Delta\theta}{\Delta t} = \frac{2\pi}{T} \quad \left(\text{For one revolution} \right)$$

$\Delta\theta = 2\pi, \Delta t = T$

Average acceleration: In uniform circular motion, the average acceleration for one revolution is zero.

Average acceleration is defined as:

$$\text{Average acceleration} = \frac{\text{Change in velocity}}{\text{time}} = \frac{0}{t} = 0$$

As change in velocity for one revolution is zero, because initial and final velocities are the same, so $\Delta\omega = 0$

The average angular acceleration is

$$\text{Average acceleration} = \frac{\text{Change in angular velocity}}{\text{Total time}} = \frac{\Delta\theta}{\Delta t} = \frac{0}{T} = 0 \quad \left(\text{For one revolution} \right)$$

$\Delta\omega = 0, \Delta t = T$

23. In a rainstorm with a strong wind, what determines the best position to hold an umbrella?

Ans. The best position to hold an umbrella in a rainstorm with strong wind is determined by the direction of the relative velocity of rain with respect to the person.

Let

$\vec{v}_{\text{rain}}$ = velocity of rain vertically downward

$\vec{v}_{\text{wind}}$ = Horizontal wind velocity

Then the relative velocity of rain is

$$\vec{v}_{\text{rel}} = \vec{v}_{\text{rain}} + \vec{v}_{\text{wind}}$$

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So for the best position, the umbrella must be titled in the direction opposite to the relative velocity of the rain.

24. A ball is just supported by a string without breaking. If it is whirled in a vertical circle, it breaks. Explain why.

Ans. When the ball is hanging, the tension (T) in the string is equal to the weight of the ball (mg) i.e.

$$T = mg$$

However, when the ball is whirled in a vertical circle, especially at the lowest point, the string must provide both the weight of the ball and the centripetal force to keep it in circular motion. The tension (T) becomes

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

Thus, the string breaks due to the additional centripetal force requirement, which increases the net tension beyond its limit.

10. How the centripetal force supplied in the following cases:

(a) A satellite orbiting around the Earth.

(b) A car taking a turn on a level road.

(c) A store whirled in a circle by means of a string.

Ans. (a) A satellite orbiting around the Earth.

In this case, centripetal force is provided by the gravitational attraction between the earth and the satellite.

According to Newton's law of gravitation

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

(b) A car taking a turn on a level road.

Here centripetal force is supplied by the frictional force between the tyres of the car and the road surface.

$$F_{\text{friction}} = \mu N = \mu mg$$

(c) A store whirled in a circle by means of a string.

In this case, the tension in the string provides the required centripetal force

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