Class : 11th

Subject : Physics

Chapter : 3

Circular and Rotational Motion

MCQs with Explanation

3.1 The ratio of angular speed of minute's hand and hour's hand of watch is:

(a) 1 : 6
(b) 6 : 1
(c) 1 : 12
✅ **(d) 12 : 1**

Explanation:

- Hour hand completes 1 round in 12 hours → $\omega h = 2\pi / 12$
- Minute hand completes 1 round in 1 hour → $\omega m = 2\pi$
- Ratio = $\omega m / \omega h = 2\pi / 2\pi/12 = 12:1$

3.2 A body traveling in a circle at constant speed:

(a) has constant velocity
✅ **(b) has an inward radial acceleration**
(c) is not accelerated
(d) has an outward radial acceleration

Explanation:
Even though speed is constant, **velocity changes due to change in direction**.
Hence, there's an **inward centripetal acceleration** acting toward the center.

3.3 The tension in the string is minimum when the stone is:

✅ **(a) at the top of the circle**
(b) half way down
(c) at the bottom of the circle
(d) anywhere in the circle

Explanation:
At the top, gravity and tension both act downward → tension is least.
At the bottom, gravity acts opposite to tension → tension is highest there.

3.4 Every point of a rotating rigid body has:

✅ **(a) same angular velocity**
(b) same linear velocity
(c) same linear acceleration
(d) same linear distance

Explanation:
All points rotate together, so **angular velocity is same**.
Linear velocity depends on distance from center → it varies.

3.5 The minimum velocity to put a satellite into orbit is called:

(a) terminal velocity
✅ **(b) critical velocity**
(c) artificial velocity
(d) angular velocity

Explanation:
Critical velocity is the exact speed needed for a satellite to remain in circular orbit without falling back to Earth.

3.6 An astronaut in orbit:

(a) will be in a state of weightlessness with respect to capsule
(b) is freely falling towards the Earth

(c) a ball projected at an angle has a straight line path as observed by him
✅ **(d) all the above**

Explanation:

- The capsule and astronaut are in free fall → weightlessness
- Everything inside moves similarly → appears stationary
- A thrown ball follows a straight line **relative** to the astronaut

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3.7 An object makes 10 revolutions in 2 seconds.

(a) Its period is 2.0 s
(b) Its period is 20 s
✅ **(c) Its frequency is 5 Hz**
(d) Its frequency is 0.2 Hz

Explanation:

Frequency=No. of revolutions / Time=10 / 2=5 Hz

3.8 A man inside the artificial satellite feels weightlessness because the force of attraction due to the Earth is:

(a) zero at pole
(b) balanced by the force of attraction due to the moon
✅ **(c) equal to the centripetal force**
(d) non-effective due to some particular design of the satellite

Explanation:
In orbit, the gravitational pull provides the **centripetal force**, so both astronaut and satellite are in free-fall → **weightlessness**.

3.9 When soda bottle is swung in vertical circle, bubbles collect:

(a) Near the bottom
(b) In the middle
(c) Bubbles remain distributed
✅ **(d) Near the neck of the bottle**

Explanation:
At the top of the circle, apparent gravity is reduced → bubbles rise and gather near the **neck** (topmost part).

3.10 Moment of inertia depends on:

(a) mass of the body and its distribution about axis of rotation
(b) volume of the body
(c) kinetic energy
(d) angular momentum

 Explanation:
Moment of Inertia $I=\sum mr^2$ → depends on **mass** and **distance from axis**.

 Short Answer Questions

3.1 *State second law of motion in case of rotation.*

The second law in rotational motion is:

$\tau = I\alpha$

Where:

- τ: torque
- I: moment of inertia
- α: angular acceleration

3.2 *What is the effect of changing the position of a diver while diving?*

When a diver tucks in (reduces body radius), **moment of inertia decreases** and **angular velocity increases** (due to conservation of angular momentum). This helps in completing more spins before entering water.

3.3 *How do we get butter from milk?*

By churning milk, we apply **circular motion** → heavier particles (liquid) move outward, lighter ones (butter fat) come to center and separate due to **centrifugal force**.

3.4 ***Mass is a measure of inertia in linear motion. What is its analogue in rotation?***

In rotation, **Moment of Inertia (I)** is analogous to mass.
It tells how much torque is needed to produce angular acceleration.

3.5 ***Why is it harder for a car to take turn at higher speed?***

Centripetal force F=mv^2r increases with **square of speed**.
So more friction is required, making it harder (and more dangerous) to turn at high speed.

3.6 ***Benefits of double rear tires on heavy vehicles:***

Double tires:

- Increase **contact area** → better grip
- Distribute **load** evenly → safer turning
- Provide **stability** and reduce risk of overturning

3.7 ***When car turns left, in which direction do occupants fall?***

They tend to fall **right** (opposite to direction of turn) due to **inertia**. Their body tries to move in a straight line while car turns left.

3.8 ***Why is acceleration of circular motion directed towards center?***

This is called **centripetal acceleration**.
It keeps the object in circular path by pulling it continuously toward center of rotation.

3.9 ***Why does astronaut feel weightless while orbiting Earth?***

Both astronaut and spacecraft are in **free-fall** around Earth.
No normal force acts on body → sensation of **weightlessness**.

Constructed Response Question

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

Answer:
No, the linear velocity of different particles will **not be constant**.

Explanation:
In a rigid body rotating with constant **angular velocity** ω\omegaω, the **linear velocity** vvv of a particle is given by:

$v = r\omega$

- r = distance of particle from the axis of rotation
- Since ω is constant but r varies for different particles,
- **Linear velocity v will differ** for each particle depending on its distance from the axis.

3.2 A loaf of bread is lying on a rotating plate. A crow takes away the loaf of bread and the plate's rotation increases. Why?

Answer:
This is due to the **law of conservation of angular momentum**.

Explanation:

- When the crow **removes the bread**, the **moment of inertia** I of the system **decreases**.
- Since there is **no external torque**, angular momentum L remains conserved:

$L = I\omega = \text{constant}$

- Therefore, if I↓, then ω↑ (angular velocity increases).

Result: The plate rotates faster after the bread is removed.

3.3 *Why do we tumble when we take the sharp turn with large speed?*

Answer:
When taking a sharp turn at high speed, the **centripetal force required increases**.

If friction between the feet (or tires) and the ground is not enough to provide this force, the body fails to stay in circular path and **tumbles outward** due to inertia.

3.4 *What will be the time period of a simple pendulum in an artificial satellite?*

Answer:
In an artificial satellite, objects are in **free-fall** (microgravity).
Since $g=0g = 0g=0$, and:

$$T=2\pi \sqrt{l/g} \Rightarrow T=\infty$$

So, **the pendulum will not oscillate**. No time period can be defined.

3.5 *Is the motion of a satellite in its orbit, uniform or accelerated?*

Answer:
The speed of satellite is constant, but direction continuously changes, so **velocity changes**.
Hence, motion is **uniform in speed** but **accelerated due to centripetal acceleration**.

3.6 *What are the advantages that radian has over degree as SI unit?*

Answer:

- Radian is a **pure ratio (arc length/radius)** → no units needed
- Makes equations in circular motion **dimensionally simpler**
- Used directly in calculus and physics formulas
  ✅ Therefore, radian is preferred over degree in SI system.

3.7 *In uniform circular motion, what are the average velocity and acceleration for one revolution?*

Answer:

- **Average velocity** over full revolution = 0, because displacement = 0
- **Average acceleration** is also **0** for same reason
  Displacement is vector → returns to starting point.

3.8 ***In a rainstorm with strong wind, where should umbrella be held?***

Answer:
Umbrella should be held in the **direction opposite to resultant velocity** of rain.
If rain falls vertically + wind blows horizontally → hold umbrella **tilted forward** to block diagonal direction.

3.9 ***A ball is just supported by a string without breaking. It breaks during vertical circular motion. Why?***

Answer:
During vertical circular motion, especially at **bottom of circle**, the tension in string becomes:

$T=mg+mv^2 / r$

This is **greater than just mg**, so it exceeds limit and **breaks the string**.

3.10 ***How is centripetal force supplied in the following cases?***

✅ **(a) Satellite orbiting Earth:**
Gravitational force between Earth and satellite provides centripetal force.

✅ **(b) Car turning on level road:**
Friction between tires and road acts as centripetal force.

✅ **(c) Stone in circular motion using string:**
Tension in string acts as centripetal force.

Comprehansive Question

3.1 What is meant by angular momentum? Explain the law of conservation of angular momentum with daily life examples.

◆ **Definition of Angular Momentum (L):**

Angular momentum is the **rotational analogue of linear momentum**.
It is the quantity of motion possessed by a rotating body.

$L = I\omega$

Where:

- L = Angular momentum
- I = Moment of inertia
- ω = Angular velocity

◆ Law of Conservation of Angular Momentum:

"If no **external torque** acts on a system, the total angular momentum of the system remains **constant**."

$L = \text{constant} \Rightarrow I_1\omega_1 = I_2\omega_2$

◆ Derivation / Mathematical Form:

If $\tau_{ext} = 0$, then:

$dL / dt = 0 \Rightarrow L = \text{constant}$

◆ Daily Life Examples:

1. Figure Skater:

When a skater pulls arms inward, moment of inertia I decreases → angular velocity ω increases → skater spins faster.

2. Ice Dancer / Diver in Air:

A diver curls the body to reduce I and spin faster before landing.

3. Neutron Star:

A dying star collapses, reducing radius → moment of inertia decreases → it spins extremely fast.

4. Spinning Plate & Bread (Crow example):

When bread is removed, moment of inertia I↓, so ω↑ → plate spins faster

3.2 Show that orbital angular momentum; $L = mvr$

Consider a particle of mass mmm moving in a circular orbit of radius rrr with linear speed v.

Angular Momentum: $L = r \times p = r \times mv = mvr$ (since $r \perp v$)

Hence proved:

$L = mvr$

Where:

- L = Angular momentum
- m = Mass
- v = Linear velocity
- r = Radius from axis

✅ 3.3 Define Moment of Inertia. Prove that torque = Iα

Definition:
Moment of inertia III is the measure of **resistance** of a rotating body to changes in its angular velocity.

$I = \sum m r^2$

Torque and Angular Acceleration:
From Newton's second law for rotation:

$\tau = I\alpha$

Derivation:
Let a mass mmm rotates in a circle of radius rrr:

$\tau = r \cdot F = r \cdot ma = r \cdot m(r\alpha) = mr2\alpha \Rightarrow \tau = I\alpha$

3.4 What are artificial satellites? Calculate minimum time period to orbit.

Definition:
Artificial satellites are man-made objects that orbit Earth or any celestial body. Example: GPS, weather satellites.

Minimum Time Period (Near Earth):

Use the formula:

$T=2\pi \sqrt{r^3 / GM}$

For lowest orbit (just above Earth): $r \approx R = 6.4\times10^6$ m
Gravitational constant: $G=6.67\times10^{-11}$
Earth mass: $M=5.97\times10^{24}$

$T=2\pi \sqrt{(6.4\times10^6)^3 / 6.67\times10^{-11}\cdot5.97\times10^{24}} \Rightarrow T\approx84.5$ minutes

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3.5 Define orbital velocity. Derive its expression.

Definition:
The minimum velocity required by a satellite to orbit Earth without falling back due to gravity.

Centripetal force = Gravitational force:

$Mv^2 / r=GMm / r^2 \Rightarrow v= \sqrt{GM / r}$ =Orbital velocity

For near-Earth orbit $r=R=6.4\times10^6$ m:

$v= \sqrt{6.67\times10^{-11}\cdot5.97\times10^{24} / 6.4\times10^6} \Rightarrow v\approx7.9$ km/s

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3.6 Write a note on artificial gravity. Derive expression for frequency.

Artificial gravity:
Created by **rotating a spaceship**. The normal reaction provides **centripetal force** that simulates gravity.

$F=m\omega^2 r=mg \Rightarrow \omega= \sqrt{g / r}$

Frequency (f):

$f=\omega / 2\pi=1 / 2\pi \sqrt{g / r} \Rightarrow f=1 / 2\pi \sqrt{g / r}$

✓ 3.7 Prove that: (i) $v = r\omega$, (ii) $a=r\alpha$

(i) Linear and angular velocity relation:

Arc length: $s=r\theta \Rightarrow ds / dt=r d\theta / dt=r\omega \Rightarrow v=r\omega$

(ii) Linear and angular acceleration relation:

$Dv / dt=r d\omega / dt=r\alpha \Rightarrow a=r\alpha$