Circular and Rotational Motion

SQ 3.1 State the second law of motion for rotation.

Rotational Law

The angular acceleration produced is directly proportional to the applied torque and inversely proportional to moment of inertia:

$\tau = I\alpha.$

SQ 3.2 What is the effect of changing the position of a diver while diving into a pool?

Angular Momentum

With negligible external torque,

$L = I\omega$

remains constant. Pulling the limbs inward decreases I and increases angular speed; extending them has the opposite effect.

SQ 3.3 How do we obtain butter from milk by using a centrifuge?

Centrifugation

Rapid rotation separates components of different densities. The denser liquid moves outward while the lighter fat gathers nearer the axis and is separated as butter.

SQ 3.4 Mass measures inertia in linear motion. What is its analogue in rotational motion?

Rotational Inertia

The analogue of mass is the moment of inertia. It depends on both the mass and its distribution about the axis:

$I = mr^2$

for a point mass.

SQ 3.5 Why is it harder for a car to turn at higher speed than at lower speed?

Centripetal Force

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

A higher speed requires much greater inward force. Limited tyre-road friction makes a fast turn more difficult and increases skidding risk.

SQ 3.6 What are the benefits of double tyres on the rear wheels of heavy vehicles?

Benefits

Double tyres provide a larger contact area, better grip and stability, and distribute the heavy load over a wider area, thereby reducing pressure on the road.

SQ 3.7 When a moving car turns left, in what direction do the occupants tend to fall? Explain.

Direction

The occupants tend to move towards the right. Their inertia tries to maintain straight-line motion while the car turns left.

SQ 3.8 Why is the acceleration of a body moving uniformly in a circle directed towards the centre?

Reason

Although speed is constant, the velocity direction changes continuously. The change in velocity points towards the centre, so the centripetal acceleration is inward.

SQ 3.9 Why does an astronaut feel weightless while orbiting the Earth in a spaceship?

Free Fall

The astronaut and spacecraft fall towards Earth with the same acceleration. No supporting normal force acts on the astronaut, producing apparent weightlessness.

CRQ 3.1 If angular velocity of different particles of a rigid body is constant, will their linear velocities also be constant?

Relation

$v = r\omega$

All particles have the same angular velocity, but their linear speeds differ with distance r from the axis. Their velocity directions also change continuously.

CRQ 3.2 A loaf of bread lies on a rotating plate. A crow removes it and the plate rotates faster. Why?

Conservation

Removing the loaf decreases the system's moment of inertia. With angular momentum conserved, $I\omega$ remains constant, so the plate's angular speed increases.

CRQ 3.3 Why do we tumble when taking a sharp turn at high speed?

Reason

A sharp fast turn requires large centripetal force. The lower body turns with the ground while the upper body tends to continue straight because of inertia, causing imbalance.

CRQ 3.4 What is the time period of a simple pendulum in an artificial satellite?

Weightlessness

Inside an orbiting satellite, effective gravity is zero. Since

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

no restoring force acts and the pendulum does not oscillate; its period is effectively infinite.

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

Motion

Its speed may be constant in a circular orbit, but its velocity direction changes. Therefore, it has centripetal acceleration and is accelerated motion.

CRQ 3.6 **Why is the radian preferred over the degree as the SI unit of angle?**

Radian

It is naturally defined by
$\theta = s/r$
is dimensionless, and gives simple relations such as
$s = r\theta$
without conversion factors.

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

Average Velocity

Displacement after one revolution is zero, so average velocity is zero.

Average Acceleration

Initial and final velocities are identical, so their change is zero and average acceleration is zero.

CRQ 3.8 **In a rainstorm with strong wind, what determines the best position for holding an umbrella?**

Relative Velocity

The umbrella should face the direction from which rain appears to come. This direction is determined by the relative velocity of rain with respect to the observer.

CRQ 3.9 **A ball is just supported by a string without breaking. Why may the string break when the ball is whirled in a vertical circle?**

Tension

At the bottom, the string must support the weight and provide centripetal force:
$T = mg + \frac{mv^2}{r}$.
This tension may exceed its breaking limit.

CRQ 3.10 **How is centripetal force supplied for (a) a satellite orbiting Earth and (b) a car turning on a level road?**

Satellite

Earth's gravitational force supplies centripetal force.

Car

The static friction between tyres and the road supplies centripetal force.