TOPIC 1 Angular Measurements

SQ 3.1.1 Define one radian.

Definition

If the length of the arc AB of a circle is equal to the radius r of the circle, then the angle subtended at the centre is called one radian.

SI Unit

It is the SI unit of angular measurement and its symbol is rad.

SQ 3.1.2 Define angular displacement.

Definition

The angle $\Delta\theta$ through which the line OP turns during a time interval Δt defines the angular displacement of OP.

SQ 3.1.3 Is angular displacement a vector quantity?

Answer

For very small values of $\Delta\theta$, the angular displacement is a vector quantity.

SQ 3.1.4 What is the sign convention for angular displacement?

Convention

The angular displacement $\Delta\theta$ is assigned a positive sign when the sense of rotation of OP is counter clockwise.

SQ 3.1.5 State the right hand rule for the direction of angular displacement.

Statement

Grasp the axis of rotation in the right hand with the fingers curling in the direction of rotation; the thumb points in the direction of angular displacement.

SQ 3.1.6 Where does the axis of rotation lie for a particle moving in a circular path?

Answer

The axis of rotation passes through the pivot O and is normal to the plane of rotation.

SQ 3.1.7 Name the three units used to express angular displacement.

Units

Three units are generally used to express angular displacement, namely degrees, revolution and radian.

SQ 3.1.8 Write the relation between arc length, radius and angle.

Formula

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

Here θ must be measured in radian.

SQ 3.1.9 How many radians are there in one revolution?

Derivation

In one revolution the point P covers a distance

$$S = 2\pi r$$

so

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

Result

$$1\text{ revolution} = 2\pi\,\text{rad} = 360^\circ$$

SQ 3.1.10 Convert one radian into degrees.

Solution

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

Result

$$1\,\text{rad} = 57.3^\circ$$

SQ 3.1.11 Define average angular velocity.

Definition

Angular velocity is the rate at which the angular displacement is changing with time.

Formula

$$\omega_{av} = \frac{\Delta\theta}{\Delta t}$$

SQ 3.1.12 Define instantaneous angular velocity.

Definition

The instantaneous angular velocity is the limit of the ratio $\dfrac{\Delta\theta}{\Delta t}$ as Δt approaches zero.

Formula

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

SQ 3.1.13 Why is instantaneous angular velocity a vector quantity?

Reason

In the limit when Δt approaches zero, the angular displacement is infinitesimally small and so it is a vector quantity. Hence the angular velocity is also a vector.

Direction

Its direction is along the axis of rotation and is given by the right hand rule.

SQ 3.1.14 Write the SI unit of angular velocity.

SI Unit

Angular velocity is measured in radians per second $(\text{rad}\,\text{s}^{-1})$.

Other Unit

Sometimes it is also given in terms of revolutions per minute (rpm).

SQ 3.1.15 Define angular acceleration.

Definition

Angular acceleration is the rate of change of angular velocity.

Formula

$$\alpha_{av} = \frac{\omega_f - \omega_i}{t_f - t_i} = \frac{\Delta\omega}{\Delta t}$$

SQ 3.1.16 **Define instantaneous angular acceleration and write its unit.**

Formula

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

Unit

Angular acceleration is expressed in $\mathrm{rad\,s^{-2}}$.

SQ 3.1.17 **Give a common example of angular acceleration.**

Example

When an electric fan is switched on, its angular velocity goes on increasing till it becomes uniform. We say that it has an angular acceleration.

SQ 3.1.18 **What is the reference line of a rotating rigid body?**

Definition

The perpendicular OP dropped from a point P of the rigid body on the axis of rotation is usually referred to as the reference line.

SQ 3.1.19 **Why can the rotation of a rigid body be described by its reference line?**

Reason

As the body rotates, the line OP also rotates with the same angular velocity and angular acceleration. Hence all the terms defined with the help of the rotating line OP are also valid for the rotational motion of the rigid body.

SQ 3.1.20 **Derive the relation between linear and angular velocity.**

Derivation

If the point P moves through ΔS while OP turns through $\Delta\theta$, then

$\Delta S = r\Delta\theta$

Dividing both sides by Δt gives

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

Result

$v = r\omega$

SQ 3.1.21 **Why is the linear velocity of a rotating point called tangential velocity?**

Reason

In the limit when $\Delta t \to 0$, the length of the arc becomes very small and its direction represents the direction of the tangent to the circle at that point. Hence the linear velocity is also known as tangential velocity.

SQ 3.1.22 **Write the relation between linear and angular acceleration.**

Formula

$a_t = r\alpha$

Here a_t is the tangential acceleration and α is the angular acceleration.

SQ 3.1.23 **Do all points of a rotating rigid body have the same speed?**

Answer

No. Points that are at different distances from the axis do not have the same speed or acceleration.

However

All points on a rigid body rotating about a fixed axis have the same angular displacement, angular speed and angular acceleration at any instant.

SQ 3.1.24 **What is the advantage of using angular variables?**

Answer

By the use of angular variables we can describe the motion of the entire body in a simple way, because all its points share the same angular quantities.

SQ 3.1.25 **Write the first equation of angular motion with its linear counterpart.**

Linear	Angular
$v_f = v_i + at$	$\omega_f = \omega_i + \alpha t$

SQ 3.1.26 **Write the second equation of angular motion with its linear counterpart.**

Linear	Angular
$S = v_i t + \frac{1}{2}at^2$	$\theta = \omega_i t + \frac{1}{2}\alpha t^2$

SQ 3.1.27 **Write the third equation of angular motion with its linear counterpart.**

Linear	Angular
$2aS = v_f^2 - v_i^2$	$2\alpha\theta = \omega_f^2 - \omega_i^2$

SQ 3.1.28 **Why are the equations of angular motion analogous to those of linear motion?**

Reason

The defining equations of angular motion are exactly analogous to those of linear motion if θ
ω and α replace S
v and a respectively. Since the other equations were obtained by algebraic manipulation, analogous equations also apply.

SQ 3.1.29 **Under what condition do the angular equations of motion hold true?**

Condition

They hold true only when the axis of rotation is fixed, so that all the angular vectors have the same direction and can be manipulated as scalars.

SQ 3.1.30 **A fan rotating at 3.0 rev s^{-1} comes to rest in 18.0 s. Find its angular deceleration.**

Solution

Using

$\alpha = \frac{\omega_f - \omega_i}{t}$

Calculation

$\alpha = \frac{0 - 3.0}{18.0}$

Result

$\alpha = -0.167\,\mathrm{rev\,s^{-2}}$

SQ 3.1.31 **How many revolutions does a fan rotating at 3.0 rev s^{-1} turn before stopping in 18.0 s?**

Solution

Using

$$\theta = \omega_i t + \frac{1}{2}\alpha t^2$$

Calculation

$$\theta = (3.0)(18.0) + \frac{1}{2}(-0.167)(18.0)^2$$

Result

$\theta = 27$ rev

SQ 3.1.32 **What is the ratio of the angular speed of the minute hand to that of the hour hand of a watch?**

Solution

The minute hand completes one revolution in 1 hour and the hour hand in 12 hours.

Result

Since $\omega \propto \dfrac{1}{T}$, the ratio is 12 : 1.

TOPIC 2 Centripetal Force

SQ 3.2.1 **What happens when a force acts along the direction of velocity of a moving body?**

Answer

A force acting on a moving body along the direction of its velocity will change the magnitude of the velocity, that is the speed, keeping the direction unchanged.

SQ 3.2.2 **What happens when a constant force acts perpendicular to the velocity of a body?**

Answer

A constant force acting perpendicular to the velocity of a body moving in a circular path will change the direction, but the magnitude of velocity will remain the same.

SQ 3.2.3 **Define centripetal force.**

Definition

The force needed to bend the straight path of a particle into a circular path is called the centripetal force.

SQ 3.2.4 **Why is centripetal force called a centre seeking force?**

Reason

This force always pulls the object towards the centre of the circular path, so it is called the centre seeking or centripetal force.

SQ 3.2.5 **What happens when the string of a whirling ball snaps?**

Answer

If the string snaps when the ball is at a point A, the ball will follow the straight line path which is the tangent to the circle at that point.

SQ 3.2.6 **Why is a force needed to keep a body moving in a circle at uniform speed?**

Reason

A force is needed to change the direction of velocity continuously at each point of the circular path. This force does not alter the speed but only the direction, and it acts along the radius of the circular path.

SQ 3.2.7 **Write the formula for centripetal force in terms of linear velocity.**

Formula

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

SQ 3.2.8 **Write the formula for centripetal force in terms of angular velocity.**

Derivation

Since

$$v = r\omega$$

the centripetal force becomes

Formula

$$F_c = mr\omega^2$$

SQ 3.2.9 **What is the direction of centripetal acceleration?**

Answer

The centripetal acceleration

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

is directed towards the centre of the circle, perpendicular to the tangential velocity at each point.

SQ 3.2.10 **What provides the centripetal force when a ball is whirled with a string?**

Answer

The tension in the string provides the necessary centripetal force.

SQ 3.2.11 **What provides the centripetal force for an object placed on a turntable?**

Answer

For an object placed on a turntable, the friction is the centripetal force.

SQ 3.2.12 **What provides the centripetal force for the Earth and artificial satellites?**

Answer

The gravitational force is the cause of the Earth orbiting around the Sun, and of the Moon and artificial satellites revolving around the Earth.

SQ 3.2.13 **How does a magnetic force act as a centripetal force?**

Answer

A normal or perpendicular magnetic force compels a charged particle moving along a straight path into a circular path.

SQ 3.2.14 **What provides the centripetal force when a vehicle takes a turn on a road?**

Answer
The centripetal force is provided by the friction between the tyres and the road.

SQ 3.2.15 **Why is it harder for a car to take a turn at higher speed?**

Reason
The required centripetal force is
$F_c = \frac{mv^2}{r}$
so it increases with the square of the speed. At high speed the friction between the tyres and the road may not be sufficient to provide it, so the vehicle may skid or even topple.

SQ 3.2.16 **Why are highway roads banked on turns?**

Reason
If the road is slippery, friction alone may not provide enough centripetal force at high speed. To overcome this difficulty the road is banked, that is the outer edge of the track is kept slightly higher than the inner edge.

SQ 3.2.17 **What happens if the applied force falls short of the required centripetal force?**

Answer
If the magnitude of the applied force falls short of the required centripetal force, then the object will move away from the centre of the circle.

SQ 3.2.18 **What is a centrifuge and on what principle does it work?**

Definition
A centrifuge is a laboratory device which helps to separate out denser and lighter particles from a mixture.
Principle
It works on the principle that if the applied force falls short of the required centripetal force, the object moves away from the centre.

SQ 3.2.19 **How does a centrifuge separate particles?**

Working
The mixture is rotated at high speed for a specific time in sample tubes. The denser particles settle at the bottom while the lighter particles rise to the top of the sample tubes.

SQ 3.2.20 **How does the dryer of a washing machine work?**

Working
The dryer consists of a long cylinder with hundreds of small holes on its wall. Wet clothes are piled in this cylinder which is rotated rapidly about its axis.
Result
Water moves outward to the walls and is drained out through the holes, so the clothes become dry quickly.

SQ 3.2.21 **How does a cream separator work?**

Working
In this machine milk is whirled rapidly. Since milk is a mixture of light and heavy particles, the light particles gather near the axis of rotation while the heavy particles go outwards.
Result
Cream can easily be separated from milk.

SQ 3.2.22 **How do we get butter from milk by using a centrifuge?**

Answer
When milk is rotated rapidly in a centrifuge, the lighter particles of cream gather near the axis of rotation while the heavier particles move outwards. The cream so separated is then churned to obtain butter.

SQ 3.2.23 **A CD of diameter 12 cm spins at 210 rpm. Find its angular velocity.**

Solution
The frequency is
$f = \frac{210}{60} = 3.5\,\mathrm{Hz}$
Calculation
$\omega = 2\pi f = 2\pi \times 3.5$
Result
$\omega = 22.0\,\mathrm{rad\,s^{-1}}$

SQ 3.2.24 **Find the radial acceleration of a point on the rim of a CD of radius 0.06 m spinning at 22.0 rad s^{-1}.**

Solution
Using
$a = \omega^2 r$
Calculation
$a = (22.0)^2 \times 0.06$
Result
$a = 29\,\mathrm{m\,s^{-2}}$

SQ 3.2.25 **A ball is swung in a vertical circle. Write the tension in the string at the lowest point A.**

Derivation
At point A two forces act on the ball, the pull of the string and the weight. Their vector sum must furnish the centripetal force, so
$T - w = \frac{mv^2}{r}.$
Result
$T = m\left(\frac{v^2}{r} - g\right)$

SQ 3.2.26 **When does the tension in the string of a ball swung in a vertical circle become zero?**

Answer
If
$\frac{v^2}{r} = g$
then the tension T becomes zero, and the centripetal force is then just equal to the weight of the ball.

SQ 3.2.27 **Why does a body travelling in a circle at constant speed have acceleration?**

Reason
Although the speed is constant, the direction of the velocity changes continuously. Hence the body has an inward radial acceleration directed towards the centre.

TOPIC 3 Artificial Satellites

SQ 3.3.1 **What are artificial satellites?**

Definition
Satellites are objects that orbit in a nearly circular path around the Earth. They are put into orbit by rockets and are held in orbit by the gravitational pull of the Earth.

SQ 3.3.2 **What is the acceleration of low flying Earth satellites?**

Answer
The low flying Earth satellites have an acceleration of $9.8\,\mathrm{m\,s^{-2}}$ towards the centre of the Earth.

SQ 3.3.3 **What would happen to a satellite if there were no gravitational pull?**

Answer
If there were no gravitational pull, the satellite would fly off in a straight line along the tangent to the orbit.

SQ 3.3.4 **What supplies the centripetal acceleration of a satellite in a circular orbit?**

Answer
In a circular orbit around the Earth, the centripetal acceleration is supplied by gravity.

Formula
$g = \dfrac{v^2}{R}$

SQ 3.3.5 **Define critical velocity and write its expression.**

Definition
The minimum velocity necessary to put a satellite into orbit is called the critical velocity.

Formula
$v = \sqrt{gR}$

SQ 3.3.6 **Calculate the critical velocity of a satellite near the Earth's surface.**

Data
Here
$g = 9.8\,\mathrm{m\,s^{-2}}$
and
$R = 6.4 \times 10^6\,\mathrm{m}$

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

Result
$v = 7.9\,\mathrm{km\,s^{-1}}$

SQ 3.3.7 **Calculate the period of a satellite orbiting close to the Earth.**

Solution
$T = \dfrac{2\pi R}{v} = \dfrac{2 \times 3.14 \times 6400}{7.9}$

Result
$T = 5060\,\mathrm{s} \approx 84$ minutes

SQ 3.3.8 **What must be taken into account for a satellite far above the Earth's surface?**

Answer
We must take into account the experimental fact that the gravitational acceleration decreases inversely as the square of the distance from the centre of the Earth.

SQ 3.3.9 **What is the effect of increasing the height of a satellite?**

Answer
The higher the satellite, the slower will be the required speed and the longer it will take to complete one revolution around the Earth.

SQ 3.3.10 **Derive the expression for the orbital velocity of a satellite.**

Derivation
The centripetal force $\dfrac{m_s v^2}{r}$ required to hold the satellite in orbit is provided by the gravitational force $\dfrac{GMm_s}{r^2}$.

Equating them gives

Result
$v = \sqrt{\dfrac{GM}{r}}$

SQ 3.3.11 **Why is the mass of a satellite unimportant in describing its orbit?**

Reason
The mass of the satellite cancels out when the gravitational force is equated to the centripetal force. Hence any satellite orbiting at distance r from the Earth's centre must have the same orbital speed.

SQ 3.3.12 **What happens if a satellite has a speed less than the required orbital speed?**

Answer
Any speed less than the required orbital speed will bring the satellite tumbling back to the Earth.

SQ 3.3.13 **Why does everything inside a satellite experience weightlessness?**

Reason
The satellite is accelerating towards the centre of the Earth as a freely falling body, so everything inside it experiences weightlessness.

SQ 3.3.14 **Which two forces act on a body suspended inside an orbiting satellite?**

Forces
Its weight mg acting downward, and the supporting or normal force F_s, that is the tension in the spring, acting upward.

SQ 3.3.15 **Show that the supporting force on a body inside a satellite is zero.**

Derivation

The resultant of the two forces provides the centripetal force, so

$F_c = mg - F_s.$

Since the centripetal force on the satellite is provided by gravity,

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

and hence

$F_c = mg$

Result

$F_s = 0$

So the bodies and astronauts in a satellite are in a state of apparent weightlessness.

SQ 3.3.16 **Why is artificial gravity needed in a spacecraft?**

Reason

If a spacecraft is to stay in orbit over an extended period of time, the weightlessness may affect the performance of the astronauts. To overcome this difficulty an artificial gravity can be created.

SQ 3.3.17 **How is artificial gravity created in a spacecraft?**

Method

The spaceship is set into rotation around its own axis. The astronaut is then pressed towards the outer rim and exerts a force on the floor of the spaceship, in much the same way as on the Earth.

SQ 3.3.18 **Derive the frequency of rotation needed to produce artificial gravity.**

Derivation

The centripetal acceleration of the outer rim is

$a_c = R\omega^2$

and with

$\omega = 2\pi f$

this becomes

$a_c = 4\pi^2 f^2 R$

For artificial gravity

$a_c = g$

therefore

Result

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

SQ 3.3.19 **An Earth satellite is 384000 km above the Earth's surface. Find the radius of its orbit.**

Solution

$r = R + h = 6400 + 384000$

Result

$r = 390400\,\text{km}$

SQ 3.3.20 **Find the period in days of a satellite whose orbital radius is 390400 km.**

Solution

The orbital speed is

$v = \sqrt{\frac{GM}{r}}$

and the period is

$T = \frac{2\pi r}{v}$

Result

$T = 27.7$ days

SQ 3.3.21 **What had Newton predicted about artificial satellites?**

Answer

Newton predicted about artificial satellites 300 years ago in his book "Principia Mathematica", stating that if an object is thrown horizontally with a particular speed from a place which is sufficiently high, it will start revolving around the Earth.

TOPIC 4 Moment of Inertia

SQ 3.4.1 **What is the rotational analogue of Newton's second law of motion?**

Formula

$\tau = mr^2\alpha$

Here F is replaced by τ

a by α and m by mr^2.

SQ 3.4.2 **State the second law of motion in the case of rotation.**

Statement

The torque acting on a body is equal to the product of its moment of inertia and its angular acceleration.

Formula

$\tau = I\alpha$

SQ 3.4.3 **Define moment of inertia of a single particle.**

Definition

The quantity mr^2 is known as the moment of inertia of a particle of mass m at a distance r from the axis of rotation.

Formula

$I = mr^2$

SQ 3.4.4 **What role does moment of inertia play in angular motion?**

Answer

The moment of inertia plays the same role in angular motion as mass does in linear motion.

SQ 3.4.5 **On what does the moment of inertia depend?**

Answer

The moment of inertia depends not only on the mass m but also on r^2, that is on the distribution of mass about the axis of rotation.

SQ 3.4.6 What is the analogue of mass in rotational motion?

Answer

Mass is a measure of inertia in linear motion, and its analogue in rotational motion is the moment of inertia. It measures the opposition of a body to a change in its rotational motion.

SQ 3.4.7 Why is the mass distribution of most rigid bodies not uniform?

Answer

Most rigid bodies have different mass concentrations at different distances from the axis of rotation, which means the mass distribution is not uniform.

SQ 3.4.8 Derive the moment of inertia of a rigid body made of many small masses.

Derivation

The torque on the first mass is

$$\tau_1 = m_1 r_1^2 \alpha$$

on the second

$$\tau_2 = m_2 r_2^2 \alpha$$

and so on.

Since each piece has the same angular acceleration, the total torque is

$$\tau = \left(\sum_{i=1}^{n} m_i r_i^2 \right) \alpha.$$

Result

$$I = \sum_{i=1}^{n} m_i r_i^2$$

SQ 3.4.9 Why does each small piece of a rigid body have the same angular acceleration?

Reason

Since the body is rigid, all the masses within it rotate together about the pivot point with the same angular acceleration.

SQ 3.4.10 Write the moment of inertia of a thin rod about an axis through its centre.

Formula

$$I = \frac{1}{12} m l^2$$

SQ 3.4.11 Write the moment of inertia of a thin ring or hoop about its central axis.

Formula

$$I = m r^2$$

SQ 3.4.12 Write the moment of inertia of a solid disc or cylinder about its central axis.

Formula

$$I = \frac{1}{2} m r^2$$

SQ 3.4.13 Write the moment of inertia of a sphere about its diameter.

Formula

$$I = \frac{2}{5} m r^2$$

SQ 3.4.14 Why does a cylinder with its mass at a larger radius have a greater moment of inertia?

Reason

The moment of inertia is

$$I = \sum m_i r_i^2$$

so it depends on the square of the distance from the axis. Two cylinders of equal mass may have different moments of inertia, and the one with the larger radius has the greater moment of inertia.

TOPIC 5 Angular Momentum

SQ 3.5.1 When is a particle said to possess angular momentum?

Definition

A particle is said to possess an angular momentum about a reference axis if it so moves that its angular position changes relative to that reference axis.

SQ 3.5.2 Define angular momentum and write its formula.

Definition

The angular momentum $\mathbf{L}$ of a particle of mass m moving with momentum $\mathbf{p}$ relative to the origin O is defined as the vector product of its position vector and momentum.

Formula

$$\mathbf{L} = \mathbf{r} \times \mathbf{p}$$

SQ 3.5.3 Write the magnitude of angular momentum.

Formula

$$L = rp \sin\theta$$

Here θ is the angle between $\mathbf{r}$ and $\mathbf{p}$.

SQ 3.5.4 What is the direction of angular momentum?

Answer

The direction of $\mathbf{L}$ is perpendicular to the plane formed by $\mathbf{r}$ and $\mathbf{p}$, and its sense is given by the right hand rule of vector product.

SQ 3.5.5 Write the SI unit of angular momentum.

SI Unit

The SI unit of angular momentum is $\mathrm{kg\,m^2 s^{-1}}$ or $\mathrm{J\,s}$.

SQ 3.5.6 Write the angular momentum of a particle moving in a circle.

Derivation

For circular motion the angle between $\mathbf{r}$ and the tangential velocity is 90°, so

$$L = mrv \sin 90^\circ$$

Since

$$v = r\omega$$

Result

$$L = mr^2\omega$$

SQ 3.5.7 **Derive the angular momentum of a rigid body about a fixed axis.**

Derivation

Each particle rotates about the same axis with angular velocity ω, and the angular momentum of the ith particle is $m_i r_i^2 \omega$.

Summing over all particles gives

$L = \left(\sum m_i r_i^2\right)\omega.$

Result

$L = I\omega$

SQ 3.5.8 **Find the orbital speed of the Earth around the Sun, given r = 1.50 × 10^{11} m and T = 3.16 × 10^7 s.**

Solution

The Earth travels a distance $2\pi r$ in one year, so

$v_0 = \dfrac{2\pi r}{T}.$

Result

$v_0 = 2.98 \times 10^4\,\mathrm{m\,s^{-1}}$

SQ 3.5.9 **Determine the orbital angular momentum of the Earth about the Sun.**

Solution

Since

$L_0 = mvr$

and

$v_0 = \dfrac{2\pi r}{T}$

therefore

$L_0 = \dfrac{2\pi r^2 m}{T}.$

Result

$L_0 = 2.67 \times 10^{40}\,\mathrm{kg\,m^2 s^{-1}}$

The sign is positive because the revolution is counter-clockwise.

TOPIC 6 Law of Conservation of Angular Momentum

SQ 3.6.1 **State the law of conservation of angular momentum.**

Statement

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

Formula

$L_{total} = L_1 + L_2 + \cdots = \text{constant}$

SQ 3.6.2 **How widely has the law of conservation of angular momentum been verified?**

Answer

The law of conservation of angular momentum is one of the fundamental principles of physics. It has been verified from the cosmological to the sub-microscopic level.

SQ 3.6.3 **What happens when an isolated spinning body alters its moment of inertia?**

Answer

If a body of moment of inertia I_1 spinning with angular speed ω_1 alters its moment of inertia to I_2, then its angular speed also changes so that the angular momentum remains constant.

Formula

$I_1\omega_1 = I_2\omega_2$

SQ 3.6.4 **Why does the axis of rotation of an object keep its orientation?**

Reason

Angular momentum is a vector quantity with direction along the axis of rotation, so this direction also remains fixed.

Statement

The axis of rotation of an object will not change its orientation unless an external torque causes it to do so.

SQ 3.6.5 **Why does the Earth's axis of rotation remain fixed in direction?**

Reason

No sizeable torque is experienced by the Earth, because the major force acting on it is the pull of the Sun. Therefore the Earth's axis of rotation remains fixed in one direction with reference to the universe around us.

SQ 3.6.6 **Explain the diving of a man from a diving board as an example of conservation of angular momentum.**

Explanation

After leaving the springboard the diver curls his body by rolling his arms and legs in. Due to this his moment of inertia decreases, and he spins in midair with a large angular velocity.

Result

When he is about to touch the water he stretches out his arms and legs, so he enters the water at a gentle speed and gets a smooth dive.

SQ 3.6.7 **What is the effect of changing the position of a diver while diving in a pool?**

Answer

When the diver curls his body, his moment of inertia decreases and his angular velocity increases. When he stretches out his arms and legs, his moment of inertia increases and his angular velocity decreases.

SQ 3.6.8 **Explain the spinning ice skater as an example of conservation of angular momentum.**

Explanation

An ice skater can increase his angular velocity by folding his arms and bringing the stretched leg close to the other leg, which decreases his moment of inertia.

Result

When he stretches his hands and leg outward the moment of inertia increases, and hence the angular velocity decreases.

SQ 3.6.9 **Explain the case of a person holding weights on a turntable.**

Explanation

A person stands on a turntable with heavy dumb-bells in his hands stretched out on both sides. As he draws his hands inward, his moment of inertia decreases.

Result

Conservation of angular momentum requires that his angular speed at once increases.

SQ 3.6.10 **Why does the duration of a day increase slightly when polar ice melts?**

Reason
When the ice on the polar caps melts, the water flows away in the form of rivers, so the moment of inertia of the water and hence of the Earth about its axis increases.

Result
By conservation of angular momentum the angular velocity of the Earth decreases, therefore the duration of the day increases slightly.

SQ 3.6.11 **What is a flywheel?**

Definition
A flywheel is a mechanical device which consists of a heavy wheel with an axle. It is used to store rotational energy, smooth out output fluctuations and provide stability.

SQ 3.6.12 **Give some applications of the flywheel.**

Applications
Flywheels are used in a wide range of applications such as bicycles and other vehicles, industrial machinery, gyroscopes, ships and spacecraft.

SQ 3.6.13 **Why is a spinning flywheel useful for stability?**

Reason
When a flywheel spins, its angular momentum resists changes to its orientation, maintaining stability. This is useful in systems that need precise control over their orientation without external interference.

SQ 3.6.14 **What is a balance wheel?**

Answer
The flywheel called the balance wheel regulates the time keeping mechanism in mechanical clocks and watches, by maintaining controlled oscillations.

SQ 3.6.15 **What is a gyroscope?**

Definition
A gyroscope is a device which is used to maintain its orientation relative to the Earth's axis, or which resists changes in its orientation. It consists of a mounted flywheel pivoted in supporting rings.

SQ 3.6.16 **Give the main applications of the gyroscope.**

Applications
The main applications of the gyroscope are in the guiding systems of aeroplanes, submarines and space vehicles, in order to maintain a specific direction in space and keep a steady course.

SQ 3.6.17 **Why does a moving bicycle remain upright while one at rest falls?**

Reason
If you try to sit on a bike at rest it falls. But if the bike is moving, the angular momentum of the spinning wheel resists any tendency to change, and this helps to keep the bike upright and stable.

SQ 3.6.18 **Why does the orbital velocity of a planet increase when it is nearer the Sun?**

Reason
Planets move around the Sun in elliptical orbits with the Sun at one focus, so the distance of a planet from the Sun is not constant.

Result
By conservation of angular momentum, when the distance decreases the moment of inertia decreases, so its orbital velocity increases automatically.

SQ 3.6.19 **Why does the rotation of a plate increase when a crow takes away a loaf of bread lying on it?**

Reason
When the loaf is removed the moment of inertia of the rotating plate decreases. Since no external torque acts, the angular momentum $I\omega$ stays constant, so the angular speed increases.