

A 8.0-cm Radius Disk With A Rotational Inertia Of 0.12 Kg M2 Is Free To Rotate On A Horizontalaxis. A

A 8.0-cm Radius Disk With A Rotational Inertia Of 0.12 Kg M2 Is Free To Rotate On A Horizontalaxis. Analyzing the dynamics of such a system provides valuable insights into rotational motion, torque, and energy conservation principles. This article explores the fundamental physics concepts involving a rotating disk, examines the calculations for various scenarios, and discusses practical applications. Whether you're a student studying rotational kinematics or an enthusiast interested in the mechanics of spinning objects, this comprehensive guide aims to clarify the essential ideas and computations related to this 8.0-cm radius disk.

Understanding the Physical Characteristics of the Disk

Dimensions and Mass Distribution

The disk in question has a radius of 8.0 centimeters, which is equivalent to 0.08 meters. Its moment of inertia (rotational inertia) is given as 0.12 kg·m². The moment of inertia is crucial because it quantifies how much torque is needed for a given angular acceleration, depending on how the mass is distributed relative to the axis of rotation.

- Radius (r): 0.08 meters
- Moment of Inertia (I): 0.12 kg·m²

The moment of inertia depends on the mass distribution. For a solid disk, the theoretical moment of inertia about its central axis is $I = \frac{1}{2} MR^2$. Given the actual inertia, one could infer the mass, but in many practical problems, the mass may be specified or calculated based on other parameters.

Mass Estimation

Assuming the disk is a solid cylinder:

$$I = \frac{1}{2} M R^2$$

Rearranging for mass (M):

$$M = \frac{2 I}{R^2}$$

\]

Plugging in the known values:

\[

$$M = \frac{2 \times 0.12}{(0.08)^2} = \frac{0.24}{0.0064} \approx 37.5,$$

\text{kg}

\]

Thus, the estimated mass of the disk is approximately 37.5 kilograms, assuming a solid disk model. This high mass indicates a substantial object, possibly made of dense material.

Fundamental Principles of Rotational Dynamics

Torque and Angular Acceleration

The core relation governing rotational motion is Newton's second law for rotation:

\[

$$\tau = I \alpha$$

\]

where:

- τ is the torque applied,
- I is the moment of inertia,
- α is the angular acceleration.

The magnitude of the torque depends on the force applied and the lever arm:

\[

$$\tau = r \times F$$

\]

If a force F is applied tangentially at the edge of the disk, the resulting angular acceleration can be calculated once the force and radius are known.

Angular Displacement and Velocity

When subjected to constant torque, the disk's angular velocity and displacement over time follow kinematic equations:

\[

$$\omega = \omega_0 + \alpha t$$

\]

\[

$$\theta = \omega_0 t + \frac{1}{2} \alpha t^2$$

\]

where:

- ω_0 is the initial angular velocity,
- ω is the angular velocity after time t ,
- θ is the angular displacement.

Scenario Analyses Involving the Disk

Scenario 1: Applying a Known Torque

Suppose a tangential force of 10 N is applied at the disk's edge. The torque is:

$$\tau = r \times F = 0.08 \text{ m} \times 10 \text{ N} = 0.8 \text{ Nm}$$

The resulting angular acceleration:

$$\alpha = \frac{\tau}{I} = \frac{0.8}{0.12} \approx 6.67 \text{ rad/s}^2$$

This acceleration indicates how quickly the disk speeds up. To find the angular velocity after 3 seconds:

$$\omega = 0 + 6.67 \times 3 = 20.01 \text{ rad/s}$$

And the angular displacement in that period:

$$\theta = 0 \times 3 + \frac{1}{2} \times 6.67 \times 3^2 = 0 + 0.5 \times 6.67 \times 9 \approx 30 \text{ rad}$$

This example demonstrates how torque influences rotational motion quantitatively.

Scenario 2: Rotational Kinetic Energy

The kinetic energy stored in a rotating disk is:

$$KE_{\text{rot}} = \frac{1}{2} I \omega^2$$

If the disk reaches an angular velocity of 20 rad/s:

$$KE_{\text{rot}} = 0.5 \times 0.12 \times (20)^2 = 0.06 \times 400 = 24 \text{ J}$$

This energy can be used to analyze energy transfer, efficiency, or to compare with other forms of energy in the system.

Scenario 3: Conservation of Energy

If the disk is initially at rest and a torque is applied to accelerate it, the work done by the torque equals the increase in rotational kinetic energy:

\[
 $W = \tau \times \theta$
\]

Alternatively, in cases where the torque is variable, calculus methods are used to evaluate work done over the angular displacement.

Practical Applications of Rotational Dynamics of Disks

Engineering and Machinery

Rotating disks are fundamental components in turbines, flywheels, and rotating machinery. Understanding their inertia and torque requirements helps engineers design efficient systems that manage energy storage and transfer.

Transportation

Wheels and rotors in vehicles depend heavily on rotational inertia to provide stability and momentum. Knowledge of how inertia affects acceleration and deceleration is vital for safety and performance optimization.

Sports and Recreation

Disks such as bicycle wheels, frisbees, or gym equipment rely on rotational principles. Athletes and designers apply these concepts to improve performance and safety.

Summary and Key Takeaways

- The physical characteristics of a rotating disk, including radius, mass, and inertia, directly influence its rotational behavior.
- Torque determines the angular acceleration; higher torque results in faster spin-up.
- The moment of inertia quantifies the distribution of mass relative to the axis, affecting the energy stored in rotation.
- Calculations involving torque, angular velocity, and energy are essential for designing and analyzing rotating systems.
- Practical applications span multiple fields, emphasizing the importance of understanding rotational dynamics.

Conclusion

Analyzing an 8.0-cm radius disk with a rotational inertia of $0.12 \text{ kg}\cdot\text{m}^2$ offers a window into the fundamental principles of rotational mechanics. Whether considering the torque needed to accelerate the disk, the energy stored during rotation, or the applications in engineering and daily life, these concepts are central to understanding how objects spin and how to control or utilize their motion effectively. Mastery of these principles enables the design of efficient mechanical systems and enhances our comprehension of the physical world.

If you have further questions about rotational dynamics or specific calculations, feel free to ask!

Frequently Asked Questions

What is the moment of inertia of the disk given its radius and rotational inertia?

The moment of inertia is provided as $0.12 \text{ kg}\cdot\text{m}^2$; the radius (8.0 cm) is used for calculations involving torque or angular acceleration, but the moment of inertia remains $0.12 \text{ kg}\cdot\text{m}^2$.

How can I calculate the angular acceleration if a torque is applied to the disk?

Angular acceleration (α) can be calculated using Newton's second law for rotation: $\alpha = \tau / I$, where τ is the applied torque and I is the moment of inertia ($0.12 \text{ kg}\cdot\text{m}^2$).

What is the rotational kinetic energy of the disk if it spins at a certain angular velocity?

The rotational kinetic energy is given by $KE = 0.5 \times I \times \omega^2$, where ω is the angular velocity in radians per second.

If a force is applied tangentially at the edge of the disk, how do I find the torque?

Torque (τ) = force $\times$ radius. For a force applied tangentially at the disk's edge, multiply the force by the radius (8.0 cm or 0.08 m).

How does the rotational inertia influence the disk's response to applied torque?

A higher rotational inertia means the disk will accelerate more slowly under a given torque, as torque is proportional to angular acceleration ($\alpha = \tau / I$).

What is the angular velocity after a certain amount of time if a constant torque is applied?

If a constant torque τ is applied, the angular velocity after time t is $\omega = \alpha \times t = (\tau / I) \times t$, assuming initial angular velocity is zero.

How do I determine the work done in spinning the disk through a certain angle?

Work done (W) is equal to the change in rotational kinetic energy: $W = 0.5 \times I \times (\omega_{\text{final}}^2 - \omega_{\text{initial}}^2)$. If starting from rest, $W = 0.5 \times I \times \omega_{\text{final}}^2$.

If the disk is initially at rest and a torque is applied for a time t , how do I find the final angular velocity?

Final angular velocity $\omega_{\text{final}} = (\tau / I) \times t$, assuming no other torques or frictional forces are acting.

What factors affect the rotational inertia of a disk, and how is it calculated?

The rotational inertia depends on the mass distribution relative to the axis. For a solid disk, $I = 0.5 \times m \times r^2$. In this case, the inertia is given as $0.12 \text{ kg}\cdot\text{m}^2$, which suggests a specific mass and distribution.

Additional Resources

A 8.0-cm Radius Disk With A Rotational Inertia Of $0.12 \text{ Kg}\cdot\text{m}^2$ Is Free To Rotate On A Horizontal Axis

Introduction

The physical properties and rotational dynamics of rigid bodies are fundamental topics in classical mechanics, with broad applications ranging from engineering to astrophysics. Among the simplest yet profoundly illustrative models is a uniform disk free to rotate about a fixed horizontal

axis. Specifically, this review examines an 8.0-cm radius disk with a rotational inertia of $0.12 \text{ kg}\cdot\text{m}^2$ —a seemingly straightforward object that embodies core principles of rotational motion, energy, and torque.

This analysis aims to explore the physical characteristics, dynamic behavior, and potential applications of such a disk, providing a comprehensive understanding suitable for educators, researchers, and enthusiasts alike. We will delve into its moment of inertia, rotational kinematics, energy considerations, and real-world relevance, framing the discussion within the context of experimental physics and engineering design.

Physical Description and Basic Properties

Geometry and Mass Distribution

The object under investigation is a disk with an 8.0-cm radius ($r = 0.08 \text{ m}$). Its rotational inertia (moment of inertia) about a central, horizontal axis is $0.12 \text{ kg}\cdot\text{m}^2$. This moment of inertia indicates how mass is distributed relative to the axis of rotation.

For a uniform solid disk, the theoretical moment of inertia about its central axis is given by:

$$I_{\text{solid}} = \frac{1}{2} M R^2$$

where (M) is the mass of the disk and (R) is its radius. Using the provided (I) , we can estimate the mass:

$$M = \frac{2I}{R^2} = \frac{2 \times 0.12 \text{ kg}\cdot\text{m}^2}{(0.08 \text{ m})^2} = \frac{0.24}{0.0064} \approx 37.5 \text{ kg}$$

Thus, the disk's approximate mass is 37.5 kg, assuming a uniform density distribution. This sizable mass suggests a dense, possibly metal-based object, suitable for experimental manipulation and demonstrations of rotational physics.

Material and Construction Considerations

Given the mass and radius, the disk's density must be significantly high if constructed from common materials like aluminum or plastic. For practical purposes, metals such as steel or cast iron are plausible candidates, which provide the necessary mass within the specified dimensions. The uniformity of the mass distribution is critical for the validity of theoretical models, so manufacturing processes ensuring uniform density are assumed.

Dynamic Analysis of the Disk

Moment of Inertia and Its Significance

The rotational inertia (I) is a measure of an object's resistance to changes in its rotational motion. The given value of $0.12 \text{ kg}\cdot\text{m}^2$ indicates a relatively significant inertia, meaning the disk resists angular acceleration unless acted upon by substantial torque.

In rotational dynamics, the fundamental relation is:

$$\tau = I \alpha$$

where τ is the torque applied and α is the angular acceleration.

This relation underpins numerous practical applications, from flywheels to rotational sensors.

Kinematic and Dynamic Equations

Suppose the disk is initially at rest and subjected to a torque τ . Its angular acceleration is:

$$\alpha = \frac{\tau}{I}$$

If a constant torque is applied, the angular velocity after time t is:

$$\omega = \alpha t = \frac{\tau}{I} t$$

Similarly, the angular displacement θ after time t is:

$$\theta = \frac{1}{2} \alpha t^2 = \frac{\tau}{2I} t^2$$

These equations are foundational for analyzing rotational motion under various force applications, including motor-driven systems or gravity-induced rotation.

Energy Considerations

Rotational Kinetic Energy

The energy stored in the rotating disk is expressed as:

$$K_{\text{rot}} = \frac{1}{2} I \omega^2$$

For example, if the disk reaches an angular velocity of $(\omega = 10 \text{ rad/s})$:

$$K_{\text{rot}} = \frac{1}{2} \times 0.12 \text{ kg}\cdot\text{m}^2 \times (10)^2 = 0.06 \times 100 = 6 \text{ J}$$

This energy can be harnessed in mechanical systems, such as flywheels, where rotational inertia stabilizes power output.

Work and Power

Applying a torque over a certain angular displacement involves work:

$$W = \tau \theta$$

The power delivered during acceleration is:

$$P = \tau \omega$$

Understanding these energy dynamics is essential for designing rotational systems with efficiency and stability in mind.

Experimental and Practical Applications

Demonstrations of Rotational Principles

The disk serves as an ideal object for illustrating fundamental physics concepts such as conservation of angular momentum, torque, and energy transfer. For example,

- Rotational Inertia Measurement: By applying known torques and measuring angular acceleration, the moment of inertia can be experimentally verified, confirming theoretical calculations.
- Gyroscopic Stability: The disk's behavior under precession and nutation can be studied, demonstrating gyroscopic effects.

- Energy Storage: Its capacity to store rotational energy makes it suitable for educational demonstrations on flywheel energy storage.

Engineering Applications

- Flywheel Energy Storage Devices: The disk's properties suggest potential as a prototype or component in flywheel systems, which store energy efficiently in rotational form.
- Mass Balancing and Vibration Damping: Rotating disks with known inertia profiles are used in precision machinery to balance rotating components or damp vibrations.
- Rotational Sensors: Encoders and gyroscopes leverage similar principles for navigation and stabilization.

Advanced Considerations: Torque, Friction, and Real-World Factors

While ideal models assume frictionless rotation and perfect rigidity, real-world applications must account for factors such as:

- Frictional Resistance: Bearing friction and air resistance lead to energy losses, affecting rotational velocity and energy retention.
- Material Fatigue: Repeated cycling can cause material fatigue, altering the moment of inertia over time.
- Alignment and Balance: Any asymmetries can introduce wobble or uneven wear, impacting system performance.

Designing systems with such disks necessitates meticulous attention to these factors, often involving lubricants, high-precision bearings, and balanced construction.

Future Directions and Research Opportunities

The simplicity of the disk belies the richness of physics it embodies. Future research could explore:

- Composite Materials: Developing disks with tailored mass distributions to optimize inertia-to-mass ratios.
- Dynamic Response under Variable Loads: Studying how the disk behaves under transient torques for applications in seismic damping or vibration control.
- Miniaturization and Micro-Scale Systems: Applying principles in MEMS devices where rotational inertia at micro scales influences device performance.

Furthermore, integrating sensors to monitor real-time rotational parameters can enhance control systems in robotics and aerospace engineering.

Conclusion

The 8.0-cm radius disk with a rotational inertia of $0.12 \text{ kg}\cdot\text{m}^2$ is more than just a simple physical object; it encapsulates core principles of rotational dynamics that are pivotal in both theoretical physics and practical engineering. Its mass distribution, energy storage capacity, and response to applied torques make it an invaluable model for educational demonstrations, experimental investigations, and technological applications.

Understanding the properties and behaviors of such a disk enables scientists and engineers to design more efficient energy storage systems, improve dynamic stability in machinery, and deepen our grasp of rotational phenomena. As technology advances, the foundational insights derived from analyzing this disk will continue to inform innovations across multiple disciplines.

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This investigative review underscores the significance of a seemingly simple rotational object, revealing the depth and breadth of physics principles it embodies and inspiring further exploration into rotational dynamics.

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