

chapter 8 rotational motion study guide answers

Published: September 27, 2026 | Index ID: #-

Chapter 8 Rotational Motion Study Guide Answers

Rotational motion is a cornerstone of classical mechanics, bridging the gap between linear dynamics and everyday experiences like spinning wheels, gears, and gyroscopes. Whether you're a high school student tackling a physics exam or a college sophomore preparing for a midterm, a solid grasp of Chapter 8's concepts is essential. This comprehensive guide delivers clear explanations, step by step problem solutions, and practical study tips—all centered around the keyword "chapter 8 rotational motion study guide answers." By the end, you'll not only know how to solve the textbook's toughest questions but also understand the physical intuition behind every equation.

1. Overview of Rotational Motion

In linear dynamics, we deal with forces, mass, and acceleration. Rotational motion extends these ideas to objects that turn around an axis. The fundamental quantities—angular displacement, angular velocity, angular acceleration, torque, and moment of inertia—mirror their linear counterparts but incorporate the geometry of rotation. Recognizing the analogies between linear and rotational equations is a powerful strategy for solving problems efficiently.

Key Analogies

- Linear displacement (s) ↔ Angular displacement (θ)
- Linear velocity (v) ↔ Angular velocity ($\omega = d\theta/dt$)
- Linear acceleration (a) ↔ Angular acceleration ($\alpha = d\omega/dt$)
- Force (F) ↔ Torque ($\tau = r \times F$)
- Mass (m) ↔ Moment of inertia (I)
- Linear momentum ($p = mv$) ↔ Angular momentum ($L = I\omega$)

By internalizing these relationships, you'll find that many chapter questions are merely variations of a few core principles.

2. Angular Velocity and Acceleration

Angular velocity, ω , measures how quickly an object rotates about an axis. It is expressed in radians per second (rad/s). Angular acceleration, α , quantifies the rate of change of ω and is measured in rad/s^2 . These quantities appear in the kinematic equations for rotational motion, analogous to linear kinematics:

1. $\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$
2. $\omega = \omega_0 + \alpha t$
3. $\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$

Understanding the derivation of these equations from their linear counterparts helps you apply them correctly, especially when initial angular velocity or displacement is zero.

Common Mistakes

- Confusing degrees with radians—always convert to radians when using the equations.
- Neglecting the sign of α or ω —a negative α indicates deceleration.

- Assuming the axis is fixed—if the axis moves, you must account for translational motion.

3. Torque and Moment of Inertia

Torque (τ) is the rotational equivalent of force. It is a vector quantity defined by $\tau = r \times F$, where r is the position vector from the axis to the point of force application, and F is the applied force. The magnitude is $\tau = rF \sin \theta$, with θ the angle between r and F . Moment of inertia (I) quantifies an object's resistance to angular acceleration, analogous to mass in linear motion. For a point mass, $I = mr^2$; for extended bodies, you integrate $I = \int r^2 dm$ over the mass distribution.

Parallel Axis Theorem

When rotating about an axis that does not pass through the center of mass, the parallel axis theorem allows you to compute I efficiently:

$$I = I_{\text{cm}} + Md^2$$

where I_{cm} is the moment of inertia about the center of mass, M is the total mass, and d is the distance between the two axes.

4. Work, Energy, and Power in Rotation

Rotational work is defined as $W = \int \tau d\theta$, where τ is the torque applied over an angular displacement θ . Rotational kinetic energy is $K = \frac{1}{2}I\omega^2$. These expressions are direct analogs of their linear forms ($W = F \cdot d$, $K = \frac{1}{2}mv^2$). Power, the rate of doing work, is $P = \tau \omega$.

When solving energy problems, remember to include both translational and rotational kinetic energy if the object moves linearly while rotating. The conservation of mechanical energy states that the sum of potential, translational kinetic, and rotational kinetic energies remains constant in the absence of non-conservative forces.

5. Angular Momentum and Conservation Laws

Angular momentum (L) is defined as $L = I\omega$. In the absence of external torque, angular momentum is conserved: $dL/dt = \tau_{\text{ext}} = 0$. This principle explains phenomena such as a figure skater pulling in their arms to spin faster. The conservation of angular momentum also applies to systems with multiple bodies, making it a powerful tool for solving multi-particle problems.

Torque and Angular Momentum Relationship

Since $\tau = dL/dt$, any change in angular momentum must arise from an applied torque. This relationship is crucial when analyzing problems that involve variable torques or changing moments of inertia.

6. Rotational Kinematics vs. Rotational Dynamics

Rotational kinematics deals with motion parameters— θ , ω , α —without reference to forces or torques. Rotational dynamics, on the other hand, involves forces (torques) and the resulting accelerations. In many textbook problems, you first determine the kinematics and then apply dynamics to find the forces or torques needed.

Problem Solving Flow

1. Identify known quantities (e.g., initial ω , θ , α).
2. Choose the appropriate kinematic equation.
3. Solve for the unknown kinematic variable.
4. Apply Newton's second law for rotation: $\tau = I\alpha$.

5. Determine the required forces or torques.

7. Common Problem Types in Chapter /8

Students often encounter the following categories of problems:

- Pure Rotational Motion: A disc rotates freely with a given angular acceleration.
- Rotating Objects with Linear Motion: A wheel rolls down an incline without slipping.
- Torque Balance: Determining the torque required to hold an object in equilibrium.
- Energy Conservation: Calculating final speeds after a change in moment of inertia.
- Angular Momentum Conservation: Predicting spin rates after collisions.
- Rotational Dynamics with External Forces: Finding the acceleration of a rotating rod under a pulling force.

Mastering each type ensures you can tackle the textbook's practice problems and the exam questions with confidence.

8. Sample Study Guide Answers

Below are detailed solutions to representative Chapter 8 questions. Each answer illustrates the reasoning process and highlights common pitfalls.

Question 1: Angular Acceleration of a Disc

A solid disc of mass 5 /kg and radius 0.3 /m is attached to a fixed axle. A horizontal force of 20 /N is applied at the rim. What is the disc's angular acceleration?

Solution:

1. Compute moment of inertia: $I = \frac{1}{2} m r^2 = \frac{1}{2} \times 5 \text{ /kg} \times (0.3 \text{ /m})^2 = 0.225 \text{ /kg}\cdot\text{m}^2$.
2. Determine torque: $\tau = r F \sin \theta = 0.3 \text{ /m} \times 20 \text{ /N} \times \sin 90^\circ = 6 \text{ /N}\cdot\text{m}$.
3. Apply $\tau = I \alpha$: $\alpha = \tau / I = 6 \text{ /N}\cdot\text{m} \div 0.225 \text{ /kg}\cdot\text{m}^2 = 26.67 \text{ /rad/s}^2$.

Check units: $\text{N}\cdot\text{m} / \text{kg}\cdot\text{m}^2 = (\text{kg}\cdot\text{m/s}^2\cdot\text{m}) / (\text{kg}\cdot\text{m}^2) = 1/\text{s}^2$, correct.

Question 2: Final Angular Speed After a Collisions

A 0.4 /kg ball is spinning at 10 /rad/s. It collides inelastically with a stationary 0.6 /kg ball fixed at the same axis. What is the final angular speed?

Solution:

1. Moments of inertia: $I_1 = \frac{1}{2} m_1 r^2$, $I_2 = \frac{1}{2} m_2 r^2$. Since the radius is the same for both, we can treat the combined mass: $I_{\text{total}} = \frac{1}{2} (m_1 + m_2) r^2$.
2. Angular momentum before collision: $L_{\text{initial}} = I_1 \omega_1$.
3. After collision, angular momentum is conserved: $L_{\text{initial}} = L_{\text{total}}$.
4. Solving: $I_1 \omega_1 = I_{\text{total}} \omega_f \Rightarrow \omega_f = \frac{I_1 \omega_1}{I_{\text{total}}} = \frac{(0.4 \text{ /kg}) \times (10 \text{ /rad/s})}{\frac{1}{2} (0.4 \text{ /kg} + 0.6 \text{ /kg}) r^2} = 4 \text{ /rad/s}$.

Thus, the final angular speed is 4 /rad/s.

Question 3: Work Done by a Torque

A torque of 15 /N·m rotates a shaft through an angular displacement of 0.5 /rad. How much work is done?

Solution:

1. Work formula: $W = \tau \theta = 15 \text{ /N}\cdot\text{m} \times 0.5 \text{ /rad} = 7.5 \text{ /J}$.

Since torque is constant, the work equals the change in rotational kinetic energy.

Question 4: Rotational Kinematics with Constant Acceleration

A wheel starts from rest and accelerates at 8 rad/s^2 . How far does it rotate in 3 seconds?

Solution:

1. Use $\theta = \omega_0 t + \frac{1}{2} \alpha t^2$; $\theta = 0 + \frac{1}{2} (8 \text{ rad/s}^2) (3 \text{ s})^2 = 0.5 \times 8 \times 9 = 36 \text{ rad}$.

So the wheel rotates 36 rad in 3 seconds.

Question 5: Parallel Axis Theorem Application

A thin hoop of mass 2 kg and radius 0.5 m rotates about an axis 0.2 m from its center. What is its moment of inertia?

Solution:

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