

chapter 8 rotational motion answers

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Introduction

Rotational motion is a cornerstone of classical mechanics, linking everyday phenomena—from a spinning wheel to the orbit of celestial bodies—with the elegant equations that describe them. Many students encounter a challenging set of problems in the eighth chapter of their physics textbooks, where the focus shifts from linear to rotational dynamics. This article offers a deep dive into **chapter 8 rotational motion answers**, presenting clear explanations, step by step solutions, and practical study strategies that will help you master the material and ace your exams.

Understanding Rotational Motion: Key Concepts

Angular Displacement, Velocity, and Acceleration

Just as linear motion is described by displacement, velocity, and acceleration, rotational motion uses angular counterparts:

- Angular displacement (θ): the angle swept by a rotating body, measured in radians.
- Angular velocity (ω): the rate of change of θ , $\omega = \frac{d\theta}{dt}$. Expressed in radians per second (rad/s).
- Angular acceleration (α): the rate of change of ω , $\alpha = \frac{d\omega}{dt}$.

These quantities are related by equations analogous to their linear counterparts:

- $\theta = \int \omega dt$
- $\omega = \frac{d\theta}{dt}$
- $\alpha = \frac{d\omega}{dt}$

Moment of Inertia

Moment of inertia (I) is the rotational equivalent of mass, quantifying how difficult it is to change an object's rotational speed. The general definition is:

$$I = \int r^2 dm$$

where m is the mass of a small element and r is its distance from the axis of rotation.

Common shapes and their moments of inertia about standard axes are:

- Solid cylinder or disk about its central axis: $I = \frac{1}{2}MR^2$
- Thin hoop or ring about its central axis: $I = MR^2$
- Solid sphere about any diameter: $I = \frac{2}{5}MR^2$
- Thin spherical shell about any diameter: $I = \frac{2}{3}MR^2$
- Rod of length L about an axis through its center and perpendicular to its length: $I = \frac{1}{12}ML^2$

Torque and Rotational Dynamics

Torque (τ) is the rotational equivalent of force. It is defined as the cross product of the radius vector and the applied force: $\tau = \mathbf{r} \times \mathbf{F}$. For a single force applied perpendicular to r , this simplifies to $\tau = rF$.

Newton's second law for rotation states:

$$\tau = I\alpha$$

When multiple torques act on a body, the net torque is the sum of each individual torque, and the resulting angular

acceleration follows from the same relationship.

Energy in Rotational Systems

The kinetic energy of a rotating body is given by:

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

When a torque does work on a rotating system, the work done equals the change in rotational kinetic energy:

$$W = \int \tau d\theta = \frac{1}{2}I(\omega_f^2 - \omega_i^2)$$

Potential energy is often considered in the context of a rotating pendulum or a rotating system in a gravitational field, where height changes translate into rotational kinetic energy.

What Is Chapter 8 in Most Physics Textbooks?

In the majority of introductory physics courses, Chapter 8 is dedicated to rotational motion. It bridges the gap between the familiar linear dynamics of Chapter 5 and the more complex topics that follow. Typical content includes:

- Derivation of torque and its relationship to angular acceleration.
- Calculating moments of inertia for various geometries.
- Exploring energy conservation in rotational systems.
- Solving problems involving rolling objects, rotating rods, and rotating disks.
- Applying the concepts to real world scenarios such as gears, flywheels, and wheels.

Students often find this chapter demanding because it requires a synthesis of multiple concepts and a strong grasp of vector relationships.

Common Questions Covered in Chapter 8 Rotational Motion Answers

Below are some of the most frequently asked questions that students encounter when working through this chapter. Each question is paired with a concise answer and, where appropriate, a brief derivation.

- How do you calculate the angular acceleration of a solid cylinder when a torque is applied? – Use $\tau = I\alpha$, with $I = \frac{1}{2}MR^2$ for a solid cylinder.
- What is the moment of inertia of a thin hoop about an axis through its center? – $I = MR^2$.
- How does kinetic energy change when a rotating disk speeds up? – KE_{rot} increases by $\frac{1}{2}I\Delta\omega^2$.
- What equation relates angular velocity and angular displacement for constant angular acceleration? – $\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$
- How do you determine the torque needed to rotate an object at a given angular acceleration? – $\tau = I\alpha$.
- What is the difference between rolling without slipping and sliding? – Rolling without slipping requires $v = R\omega$ where v is linear speed and R is radius; sliding allows relative motion at the contact point.

Step by Step Solutions to Popular Problems

Problem 1: Rotating Disk with Applied Torque

Question: A solid disk of mass 4 kg and radius 0.5 m is free to rotate about its central axis. A constant torque of 10 N·m is applied. What is the angular acceleration and the angular velocity after 3 s?

1. Compute the moment of inertia: $I = \frac{1}{2}MR^2 = \frac{1}{2}(4 \text{ kg})(0.5 \text{ m})^2 = 0.5 \text{ kg}\cdot\text{m}^2$.
2. Apply $\tau = I\alpha$ to find angular acceleration: $\alpha = \tau / I = 10 \text{ N}\cdot\text{m} / 0.5 \text{ kg}\cdot\text{m}^2 = 20 \text{ rad/s}^2$.
3. Use $\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$; Assuming the disk starts from rest ($\omega_i = 0$): $\omega_f = \sqrt{2\alpha\Delta\theta} = \sqrt{2(20 \text{ rad/s}^2)(9 \text{ s})} = 60 \text{ rad/s}$.

Answer: The disk's angular acceleration is 20 rad/s^2 , and after 3 seconds its angular velocity is 60 rad/s .

Problem 2: Rolling Cylinder Without Slipping

Question: A solid cylinder of mass 2 kg and radius 0.3 m rolls down an incline of 30° without slipping. Determine the linear acceleration of its center of mass.

1. Set up the free body diagram: gravitational component along the incline: $mg \sin \theta$; Normal force N perpendicular to the incline; friction force f up the incline.
2. Normal force cancels the perpendicular component; friction provides torque but does no work.
3. Apply Newton's second law for rotation: $\tau = I\alpha$, where $\tau = fR$ and $I = \frac{1}{2}MR^2$.
4. Relate linear acceleration (a) to angular acceleration: $a = R\alpha$.
5. Combine equations: $fR = \frac{1}{2}MR^2(a/R)$ $\Rightarrow f = \frac{1}{2}Ma$.
6. Apply Newton's second law for translation: $mg \sin \theta - f = Ma$.
7. Substitute f : $mg \sin \theta - \frac{1}{2}Ma = Ma$ $\Rightarrow 1.5Ma = mg \sin \theta$.
8. Solve for a : $a = \frac{mg \sin \theta}{1.5M} = \frac{2 \text{ kg} \cdot 9.81 \text{ m/s}^2 \cdot \sin 30^\circ}{1.5 \cdot 2 \text{ kg}} = 9.81 \text{ m/s}^2$.

Answer: The cylinder's center of mass accelerates down the incline at approximately 3.27 m/s^2 .

Problem 3: Rotational Kinetic Energy and Work Done

Question: A flywheel of mass 5 kg and radius 1 m is initially at rest. A constant torque of $15 \text{ N}\cdot\text{m}$ is applied for 10 s. Calculate the work done on the flywheel and its final rotational kinetic energy.

1. Moment of inertia: $I = \frac{1}{2}MR^2 = \frac{1}{2}(5 \text{ kg})(1 \text{ m})^2 = 2.5 \text{ kg}\cdot\text{m}^2$.
2. Angular acceleration: $\alpha = \tau / I = 15 \text{ N}\cdot\text{m} / 2.5 \text{ kg}\cdot\text{m}^2 = 6 \text{ rad/s}^2$.
3. Final angular velocity: $\omega = \alpha t = 6 \text{ rad/s}^2 \times 10 \text{ s} = 60 \text{ rad/s}$.
4. Rotational kinetic energy: $KE_{\text{rot}} = \frac{1}{2}I\omega^2 = \frac{1}{2}(2.5 \text{ kg}\cdot\text{m}^2)(60 \text{ rad/s})^2 = 4,500 \text{ J}$.

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