

Solutions to: [Elder] Angular Momentum Practice

1.

IDENTIFY: Apply conservation of angular momentum.

SET UP: For a uniform sphere and an axis through its center, $I = \frac{2}{5}MR^2$.

EXECUTE: The moment of inertia is proportional to the square of the radius, and so the angular velocity will be proportional to the inverse of the square of the radius, and the final angular velocity is

$$\omega_2 = \omega_1 \left(\frac{R_1}{R_2} \right)^2 = \left(\frac{2\pi \text{ rad}}{(30 \text{ d})(86,400 \text{ s/d})} \right) \left(\frac{7.0 \times 10^5 \text{ km}}{16 \text{ km}} \right)^2 = 4.6 \times 10^4 \text{ rad/s.}$$

EVALUATE: $K = \frac{1}{2}I\omega^2 = \frac{1}{2}L\omega$. L is constant and ω increases by a large factor, so there is a large increase in the rotational kinetic energy of the star. This energy comes from potential energy associated with the gravity force within the star.

2.

IDENTIFY: Apply conservation of angular momentum to the motion of the skater.

SET UP: For a thin-walled hollow cylinder $I = mR^2$. For a slender rod rotating about an axis through its center, $I = \frac{1}{12}ml^2$.

EXECUTE: $L_i = L_f$ so $I_i\omega_i = I_f\omega_f$.

$$I_i = 0.40 \text{ kg} \cdot \text{m}^2 + \frac{1}{12}(8.0 \text{ kg})(1.8 \text{ m})^2 = 2.56 \text{ kg} \cdot \text{m}^2. \quad I_f = 0.40 \text{ kg} \cdot \text{m}^2 + (8.0 \text{ kg})(0.25 \text{ m})^2 = 0.90 \text{ kg} \cdot \text{m}^2.$$

$$\omega_f = \left(\frac{I_i}{I_f} \right) \omega_i = \left(\frac{2.56 \text{ kg} \cdot \text{m}^2}{0.90 \text{ kg} \cdot \text{m}^2} \right) (0.40 \text{ rev/s}) = 1.14 \text{ rev/s.}$$

EVALUATE: $K = \frac{1}{2}I\omega^2 = \frac{1}{2}L\omega$. ω increases and L is constant, so K increases. The increase in kinetic energy comes from the work done by the skater when he pulls in his hands.

3.

IDENTIFY: Apply conservation of angular momentum to the system of earth plus asteroid.

SET UP: Take the axis to be the earth's rotation axis. The asteroid may be treated as a point mass and it has zero angular momentum before the collision, since it is headed toward the center of the earth. For the earth, $L_i = I\omega_i$ and $I = \frac{2}{5}MR^2$, where M is the mass of the earth and R is its radius. The length of a day is

$$T = \frac{2\pi \text{ rad}}{\omega}, \text{ where } \omega \text{ is the earth's angular rotation rate.}$$

EXECUTE: Conservation of angular momentum applied to the collision between the earth and asteroid

$$\text{gives } \frac{2}{5}MR^2\omega_i = (mR^2 + \frac{2}{5}MR^2)\omega_2 \text{ and } m = \frac{2}{5}M \left(\frac{\omega_i - \omega_2}{\omega_2} \right). \quad T_2 = 1.250T_1 \text{ gives } \frac{1}{\omega_2} = \frac{1.250}{\omega_1} \text{ and}$$

$$\omega_1 = 1.250\omega_2, \quad \frac{\omega_1 - \omega_2}{\omega_2} = 0.250. \quad m = \frac{2}{5}(0.250)M = 0.100M.$$

EVALUATE: If the asteroid hit the surface of the earth tangentially it could have some angular momentum with respect to the earth's rotation axis, and could either speed up or slow down the earth's rotation rate.

Angular Momentum Practice Problems And Solutions

Greg Jacobs



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Table of Contents Angular Momentum Practice Problems And Solutions

1. Understanding the eBook Angular Momentum Practice Problems And Solutions
 - The Rise of Digital Reading Angular Momentum Practice Problems And Solutions
 - Advantages of eBooks Over Traditional Books
2. Identifying Angular Momentum Practice Problems And Solutions
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Angular Momentum Practice Problems And Solutions
 - User-Friendly Interface
4. Exploring eBook Recommendations from Angular Momentum Practice Problems And Solutions
 - Personalized Recommendations
 - Angular Momentum Practice Problems And Solutions User Reviews and Ratings
 - Angular Momentum Practice Problems And Solutions and Bestseller Lists
5. Accessing Angular Momentum Practice Problems And Solutions Free and Paid eBooks
 - Angular Momentum Practice Problems And Solutions Public Domain eBooks
 - Angular Momentum Practice Problems And Solutions eBook Subscription Services

- Angular Momentum Practice Problems And Solutions Budget-Friendly Options
- 6. Navigating Angular Momentum Practice Problems And Solutions eBook Formats
 - ePub, PDF, MOBI, and More
 - Angular Momentum Practice Problems And Solutions Compatibility with Devices
 - Angular Momentum Practice Problems And Solutions Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Angular Momentum Practice Problems And Solutions
 - Highlighting and Note-Taking Angular Momentum Practice Problems And Solutions
 - Interactive Elements Angular Momentum Practice Problems And Solutions
- 8. Staying Engaged with Angular Momentum Practice Problems And Solutions
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Angular Momentum Practice Problems And Solutions
- 9. Balancing eBooks and Physical Books Angular Momentum Practice Problems And Solutions
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Angular Momentum Practice Problems And Solutions
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Angular Momentum Practice Problems And Solutions
 - Setting Reading Goals Angular Momentum Practice Problems And Solutions
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Angular Momentum Practice Problems And Solutions
 - Fact-Checking eBook Content of Angular Momentum Practice Problems And Solutions
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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