

## Chapter 8 Supplemental Problems Rotational Motion Answers

Chapter 8 Supplemental Problems Rotational Motion Answers Chapter 8 Supplemental Problems Rotational Motion Answers This document provides detailed solutions to the supplemental problems presented in Chapter 8 of your textbook covering the fundamentals of rotational motion. These problems are designed to challenge your understanding of concepts such as angular velocity, angular acceleration, torque, moment of inertia, and conservation of angular momentum. By working through these problems, you will gain a deeper understanding of the principles governing rotational motion and their application in various physical scenarios.

Rotational Motion Angular Velocity Angular Acceleration Torque Moment of Inertia Conservation of Angular Momentum Supplemental Problems Solutions This document provides comprehensive solutions to a set of supplemental problems designed to reinforce and enhance your understanding of rotational motion. Each problem is carefully analyzed, outlining the relevant concepts, equations, and steps involved in reaching the final answer. The solutions are presented in a clear and concise manner, utilizing diagrams and detailed explanations to facilitate comprehension.

**Solutions**

**Problem 1** The Spinning Disk

A solid disk of mass  $M$  and radius  $R$  is rotating about an axis through its center with an angular velocity  $\omega$ . What is the kinetic energy of the disk?

**Solution** The kinetic energy of a rotating object is given by  $K = \frac{1}{2}I\omega^2$ , where  $I$  is the moment of inertia of the object. For a solid disk rotating about its center, the moment of inertia is  $I = \frac{1}{2}MR^2$ . Substituting this into the kinetic energy equation, we get  $K = \frac{1}{2}\frac{1}{2}MR^2\omega^2 = \frac{1}{4}MR^2\omega^2$ .

**Problem 2** The Rolling Cylinder

A solid cylinder of mass  $M$  and radius  $R$  rolls without slipping down an incline of angle  $\theta$ . What is the linear acceleration of the cylinder?

**Solution** The linear acceleration of the cylinder can be found using the following steps:

1. Draw a free body diagram. The forces acting on the cylinder are gravity  $Mg$ , the normal force  $N$ , and friction  $f$ .
2. Apply Newton's second law:  $F_x = Ma$ ,  $F_y = Mg \sin \theta - N = 0$ ,  $F_f = f = Mg \cos \theta$ .
3. Apply the rotational equivalent of Newton's second law: torque  $I\alpha = fR$ . Where  $\alpha$  is the angular acceleration and  $I$  is the moment of inertia of the cylinder,  $I = \frac{1}{2}MR^2$ .
4. Relate linear and angular acceleration: For rolling without slipping,  $a = R\alpha$ .
5. Solve for the linear acceleration  $a$ . Using the above equations, we can solve for  $a$  to obtain  $a = \frac{2}{3}g \sin \theta$ .

**Problem 3** The Rotating Rod

A uniform rod of length  $L$  and mass  $M$  is pivoted at one end and allowed to swing freely. What is the period of oscillation for small angles?

**Solution** The period of oscillation for a physical pendulum is given by  $T = 2\pi\sqrt{\frac{I}{Mgd}}$ , where  $I$  is the moment of inertia about the pivot point,  $m$  is the mass, and  $d$  is the distance from the pivot point to the center of mass. For a rod pivoted at one end, the moment of inertia is  $I = \frac{1}{3}ML^2$ . The center of mass is at a distance  $\frac{L}{2}$  from the pivot point, so  $d = \frac{L}{2}$ . Substituting these values into the equation for the period, we get  $T = 2\pi\sqrt{\frac{\frac{1}{3}ML^2}{Mg\frac{L}{2}}} = 2\pi\sqrt{\frac{2L}{3g}}$ .

one end the moment of inertia about the pivot is  $I = 1/3ML^2$ . The distance from the pivot to the center of mass is  $L/2$ . Substituting these values into the period equation we get  $T = 2\pi\sqrt{3ML^2/2\pi^2L^3g} = 2\pi\sqrt{M/2\pi^2g}$ . Problem 4 The Conservation of Angular Momentum A figure skater is spinning with an initial angular velocity  $\omega_i$ . She then extends her arms increasing her moment of inertia from  $I_i$  to  $I_f$ . What is her final angular velocity  $\omega_f$ ? Solution The principle of conservation of angular momentum states that in the absence of external torques the total angular momentum of a system remains constant. Mathematically this can be expressed as  $I_i\omega_i = I_f\omega_f$ . Solving for  $\omega_f$  we get  $\omega_f = I_i\omega_i/I_f$ . Since the figure skater increases her moment of inertia her final angular velocity will decrease. Problem 5 The Rotating Platform A rotating platform is initially spinning with an angular velocity  $\omega$ . A person standing at the 4/5 edge of the platform throws a ball horizontally in the same direction as the platform's rotation. Does the platform's angular velocity increase, decrease, or remain the same? Solution The platform's angular velocity will decrease. When the person throws the ball they are essentially transferring some of their angular momentum to the ball. Since angular momentum is conserved the platform must lose angular momentum to compensate. This results in a decrease in the platform's angular velocity. Conclusion By working through these supplemental problems you have developed a deeper understanding of the key concepts governing rotational motion. You've explored how these concepts are applied in various physical scenarios from spinning disks to rolling cylinders to swinging rods. Remember understanding rotational motion is crucial not only for understanding the physical world around us but also for countless engineering and scientific applications.

FAQs

1. What is the difference between linear and angular velocity? Linear velocity describes the rate of change of an object's position in a straight line while angular velocity describes the rate of change of an object's angular position.
2. How does the concept of torque relate to rotational motion? Torque is the rotational equivalent of force. It is a force applied at a distance from an axis of rotation causing the object to rotate.
3. What is the significance of the moment of inertia in rotational motion? The moment of inertia is a measure of an object's resistance to changes in its rotational motion. It depends on the object's mass distribution and its shape.
4. How does the conservation of angular momentum apply to real-world scenarios? Conservation of angular momentum is a fundamental principle that applies to a wide range of phenomena from the spinning of planets to the angular momentum of atoms. It is also important in engineering applications such as the design of spinning machines and spacecraft.
5. What are some real-world examples of rotational motion? Examples include spinning wheels, rotating gears, a spinning top, a carousel, and the rotation of the Earth.

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