CHAPTER 9 | ROTATIONAL DYNAMICS

CONCEPTUAL QUESTIONS

5. **REASONING AND SOLUTION** Work and torque are both the product of force and distance. Work and torque are distinctly different physical quantities, as is evident by considering the distances in the definitions. Work is defined by \( W = (F \cos \theta) s \), according to Equation 6.1, where \( F \) is the magnitude of the force, \( \theta \) is the angle between the force and the displacement, and \( s \) is the magnitude of the displacement. The magnitude of the torque is defined as the magnitude of the force times the lever arm, according to Equation 9.1. In the definition of work, the "distance" is the magnitude of the displacement over which the force acts. In the definition of torque, the distance is the lever arm, a "static" distance. The lever arm is not the same physical quantity as the displacement. Therefore, work and torque are different quantities.

CHAPTER 9 | ROTATIONAL DYNAMICS

PROBLEMS

32. **REASONING** The rotational analog of Newton's second law is given by Equation 9.7, \( \sum \tau = I \alpha \). Since the person pushes on the outer edge of one pane of the door with a force \( F \) that is directed perpendicular to the pane, the torque exerted on the door has a magnitude of \( FL \), where the lever arm \( L \) is equal to the width of one pane of the door. Once the moment of inertia is known, Equation 9.7 can be solved for the angular acceleration \( \alpha \).

The moment of inertia of the door relative to the rotation axis is \( I = 4I_p \), where \( I_p \) is the moment of inertia for one pane. According to Table 9.1, we find \( I_p = \frac{1}{3}ML^2 \), so that the rotational inertia of the door is \( I = \frac{4}{3}ML^2 \).

**SOLUTION** Solving Equation 9.7 for \( \alpha \), and using the expression for \( I \) determined above, we have

\[
\alpha = \frac{FL}{\frac{4}{3}ML^2} = \frac{F}{\frac{4}{3}ML} = \frac{68 \text{ N}}{\frac{4}{3}(85 \text{ kg})(1.2 \text{ m})} = 0.50 \text{ rad/s}^2
\]

46. **REASONING**

a. The kinetic energy is given by Equation 9.9 as \( KE = \frac{1}{2}I\omega^2 \). Assuming the earth to be a uniform solid sphere, we find from Table 9.1 that the moment of inertia is \( I = \frac{2}{5}MR^2 \). The mass and radius of the earth is \( M = 5.98 \times 10^{24} \text{ kg} \) and \( R = 6.38 \times 10^6 \text{ m} \) (see the inside of the text’s front cover). The angular speed \( \omega \) must be expressed in rad/s, and we note that the earth turns once around its axis each day, which corresponds to \( 2\pi \text{ rad/day} \).

b. The kinetic energy for the earth’s motion around the sun can be obtained from Equation 9.9 as \( KE = \frac{1}{2}I\omega^2 \). Since the earth’s radius is small compared to the radius of the earth’s orbit \( (R_{\text{orbit}} = 1.50 \times 10^{11} \text{ m}, \text{see the inside of the text’s front cover}) \), the moment of inertia in this case is
just \( I = MR^2 \). The angular speed \( \omega \) of the earth as it goes around the sun can be obtained from the fact that it makes one revolution each year, which corresponds to \( 2\pi \) rad/year.

**SOLUTION**

a. According to Equation 9.9, we have

\[
 KE_R = \frac{1}{2} I \omega^2 = \frac{1}{2} GM R^2 \omega^2
\]

\[
= \frac{1}{2} \left[ \frac{2}{5} \times 9.8 \times 10^{24} \text{ kg} \times 3.8 \times 10^{6} \text{ m} \right] \times \frac{2 \pi \text{ rad}}{365 \text{ day}} \times \frac{24 \text{ h}}{1 \text{ day}} \times \frac{1 \text{ h}}{3600 \text{ s}}
\]

\[
= 2.57 \times 10^{29} \text{ J}
\]

b. According to Equation 9.9, we have

\[
 KE_R = \frac{1}{2} I \omega^2 = \frac{1}{2} GM R^2 \omega^2
\]

\[
= \frac{1}{2} \times 9.8 \times 10^{24} \text{ kg} \times 5.0 \times 10^{11} \text{ m} \]

\[
= \frac{2 \pi \text{ rad}}{11 \text{ yr}} \times \frac{365 \text{ day}}{1 \text{ yr}} \times \frac{1 \text{ day}}{24 \text{ h}} \times \frac{1 \text{ h}}{3600 \text{ s}}
\]

\[
= 2.67 \times 10^{33} \text{ J}
\]

55. **REASONING AND SOLUTION**

a. Angular momentum is conserved, so that \( I \omega = I_o \omega_o \), where

\[
I = I_o + 10m_b R_b^2 = 2100 \text{ kg} \cdot \text{m}^2
\]

\[
\omega = \frac{(I_o/I) \omega_o}{(1500 \text{ kg} \cdot \text{m}^2)/(2100 \text{ kg} \cdot \text{m}^2)} = 0.14 \text{ rad/s}
\]

b. A net external torque must be applied in a direction that is opposite to the angular deceleration caused by the baggage dropping onto the carousel.

**CHAPTER 11 | FLUIDS**

**CONCEPTUAL QUESTIONS**

3. **REASONING AND SOLUTION** A person could not balance her entire weight on the pointed end of a single nail, because it would penetrate her skin. According to Equation 11.3, the pressure exerted by the nail is \( P = F / A \) where \( F \) represents the weight of the person, and \( A \) is the area of the tip of the nail. Since the tip of the nail has a very small radius, its area is very small; therefore, the pressure that the nail exerts on the person is large. The reason she can safely lie on a "bed of nails" is that the effective area of the nails is very large if the nails are closely spaced. Thus, the weight of the person \( F \) is distributed over all the nails so that the pressure exerted by any one nail is small.
5. **REASONING AND SOLUTION** The bottle of juice is sealed under a partial vacuum. Therefore, when the seal is intact, the button remains depressed, because the pressure inside the bottle is less than the atmospheric pressure outside of the bottle. The force per unit area pushing up on the button from the inside is significantly smaller than the force per unit area pushing down on the outside. When the seal is broken, air rushes inside the bottle. The force pushing up on the button increases and offsets the force pushing down. The natural springiness of the material from which the lid is made can then make the button "pop up."

### CHAPTER 11  FLUIDS

#### PROBLEMS

5. **SSM REASONING** Equation 11.1 can be used to find the volume occupied by 1.00 kg of silver. Once the volume is known, the area of a sheet of silver of thickness \( d \) can be found from the fact that the volume is equal to the area of the sheet times its thickness.

**SOLUTION** Solving Equation 11.1 for \( V \), the volume of 1.00 kg of silver is

\[
V = \frac{m}{\rho} = \frac{1.00 \text{ kg}}{10\,500 \text{ kg/m}^3} = 9.52 \times 10^{-5} \text{ m}^3
\]

The area of the silver, is, therefore,

\[
A = \frac{V}{d} = \frac{9.52 \times 10^{-5} \text{ m}^3}{3.00 \times 10^{-7} \text{ m}} = 317 \text{ m}^2
\]

12. **REASONING** Pressure is the magnitude of the force applied perpendicularly to a surface divided by the area of the surface, according to Equation 11.3. The force magnitude, therefore, is equal to the pressure times the area.

**SOLUTION** According to Equation 11.3, we have

\[
F = PA = 8.0 \times 10^4 \text{ lb/in}^2 \cdot \text{lb/in.}^2 \cdot \text{in.} = 1.3 \times 10^6 \text{ lb}
\]

21. **REASONING** The magnitude of the force that would be exerted on the window is given by Equation 11.3, \( F = PA \), where the pressure can be found from Equation 11.4: \( P_2 = P_1 + \rho gh \). Since \( P_1 \) represents the pressure at the surface of the water, it is equal to atmospheric pressure, \( P_{\text{atm}} \). Therefore, the magnitude of the force is given by

\[
F = (P_{\text{atm}} + \rho gh) A
\]

where, if we assume that the window is circular with radius \( r \), its area \( A \) is given by \( A = \pi r^2 \).

**SOLUTION**

a. Thus, the magnitude of the force is
\[ F = \left[ 1.013 \times 10^5 \text{ Pa} + (1025 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(11000 \text{ m}) \right] \pi (0.10 \text{ m})^2 = 3.5 \times 10^6 \text{ N} \]

b. The weight of a jetliner whose mass is \( 1.2 \times 10^5 \text{ kg} \) is

\[ W = mg = (1.2 \times 10^5 \text{ kg})(9.80 \text{ m/s}^2) = 1.2 \times 10^6 \text{ N} \]

Therefore, the force exerted on the window at a depth of 11000 m is about three times greater than the weight of a jetliner!