Chapter 10

1. The problem asks us to assume v_{com} and ω are constant. For consistency of units, we write

$$v_{\text{com}} = (85\,\text{mi/h})\left(\frac{5280\,\text{ft/mi}}{60\,\text{min/h}}\right) = 7480\,\text{ft/min}\ .$$

Thus, with $\Delta x = 60\,\text{ft}$, the time of flight is

$$t = \Delta x / v_{\text{com}} = (60\ \text{ft})/(7480\ \text{ft/min}) = 0.00802\,\text{min}\,.$$

During that time, the angular displacement of a point on the ball's surface is

$$\theta = \omega t = (1800\,\text{rev/min})(0.00802\,\text{min}) \approx 14\,\text{rev}\ .$$

2. (a) The second hand of the smoothly running watch turns through 2π radians during $60\ \text{s}$. Thus,

$$\omega = \frac{2\pi}{60} = 0.105\ \text{rad/s}.$$

(b) The minute hand of the smoothly running watch turns through 2π radians during $3600\ \text{s}$. Thus,

$$\omega = \frac{2\pi}{3600} = 1.75\times 10^{-3}\ \text{rad / s}.$$

(c) The hour hand of the smoothly running 12-hour watch turns through 2π radians during 43200 s. Thus,

$$\omega = \frac{2\pi}{43200} = 1.45\times 10^{-4}\ \text{rad / s}.$$

12. (a) We assume the sense of rotation is positive. Applying Eq. 10-12, we obtain

$$\omega = \omega_0 + \alpha t \quad \Rightarrow \quad \alpha = \frac{(3000 - 1200)\ \text{rev/min}}{(12/60)\ \text{min}} = 9.0\times 10^{3}\ \text{rev/min}^{2}.$$

(b) And Eq. 10-15 gives

$$\theta = \frac{1}{2}(\omega_0 + \omega)t = \frac{1}{2}(1200\ \text{rev/min} + 3000\ \text{rev/min})\left(\frac{12}{60}\ \text{min}\right) = 4.2\times 10^{2}\ \text{rev}.$$

16. (a) Eq. 10-13 gives

$$\theta - \theta_0 = \omega_0 t + \tfrac{1}{2}\alpha t^2 = 0 + \tfrac{1}{2}(1.5 \text{ rad/s}^2) t_1^2$$

where $\theta - \theta_0$ = (2 rev)(2π rad/rev). Therefore, t_1 = 4.09 s.

(b) We can find the time to go through a full 4 rev (using the same equation to solve for a new time t_2) and then subtract the result of part (a) for t_1 in order to find this answer.

$$(4 \text{ rev})(2\pi \text{ rad/rev}) = 0 + \tfrac{1}{2}(1.5 \text{ rad/s}^2) t_2^2 \quad \Rightarrow \quad t_2 = 5.789 \text{ s}.$$

Thus, the answer is 5.789 s – 4.093 s ≈ 1.70 s.

34. (a) Equation 10-12 implies that the angular acceleration α should be the slope of the ω vs t graph. Thus, α = 9/6 = 1.5 rad/s^2.

(b) By Eq. 10-34, K is proportional to ω^2. Since the angular velocity at t = 0 is –2 rad/s (and this value squared is 4) and the angular velocity at t = 4 s is 4 rad/s (and this value squared is 16), then the ratio of the corresponding kinetic energies must be

$$\frac{K_o}{K_4} = \frac{4}{16} \quad \Rightarrow \quad K_o = K_4/4 = 0.40 \text{ J} .$$

48. We compute the torques using $\tau = rF \sin \phi$.

(a) For $\phi = 30°$, $\tau_a = (0.152 \text{ m})(111 \text{ N}) \sin 30° = 8.4 \text{ N} \cdot \text{m}$.

(b) For $\phi = 90°$, $\tau_b = (0.152 \text{ m})(111 \text{ N}) \sin 90° = 17 \text{ N} \cdot \text{m}$.

(c) For $\phi = 180°$, $\tau_c = (0.152 \text{ m})(111 \text{ N}) \sin 180° = 0$.

50. The rotational inertia is found from Eq. 10-45.

$$I = \frac{\tau}{\alpha} = \frac{32.0}{25.0} = 1.28 \text{ kg} \cdot \text{m}^2$$

77. **THINK** The record turntable comes to a stop due to a constant angular acceleration. We apply equations given in Table 10-1 to analyze the rotational motion.

EXPRESS We take the sense of initial rotation to be positive. Then, with $\omega_0 > 0$ and ω = 0 (since it stops at time t), our angular acceleration is negative-valued. The angular acceleration is constant, so we can apply Eq. 10-12 ($\omega = \omega_0 + \alpha t$), which gives

$\alpha = (\omega - \omega_0)/t$. Similarly, the angular displacement can be found by using Eq. 10-13: $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$.

ANALYZE (a) To obtain the requested units, we use t = 30 s = 0.50 min. With $\omega_0 = 33.33$ rev/min, we find the angular acceleration to be

$$\alpha = -\frac{33.33\text{ rev/min}}{0.50\text{ min}} = -66.7\text{ rev/min}^2 \approx -67\text{ rev/min}^2.$$

(b) Substituting the value of α obtained above into Eq. 10-13, we get

$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2 = (33.33\text{ rev/min})(0.50\text{ min}) + \frac{1}{2}(-66.7\text{rev/min}^2)(0.50\text{ min})^2 = 8.33\text{ rev}.$$

LEARN To solve for the angular displacement in (b), we may also use Eq. 10-15:

$$\theta = \frac{1}{2}(\omega_0 + \omega)t = \frac{1}{2}(33.33\text{ rev/min} + 0)(0.50\text{ min}) = 8.33\text{ rev}.$$

88. (a) We use $\tau = I\alpha$, where τ is the net torque acting on the shell, I is the rotational inertia of the shell, and α is its angular acceleration. Therefore,

$$I = \frac{\tau}{\alpha} = \frac{960\text{ N}\cdot\text{m}}{6.20\text{ rad/s}^2} = 155\text{ kg}\cdot\text{m}^2.$$

(b) The rotational inertia of the shell is given by $I = (2/3)\, MR^2$ (see Table 10-2 of the text). This implies

$$M = \frac{3I}{2R^2} = \frac{3(155\text{ kg}\cdot\text{m}^2)}{2(1.90\text{ m})^2} = 64.4\text{ kg}.$$

89. Equation 10-40 leads to $\tau = mgr$ = (70 kg) (9.8 m/s^2) (0.20 m) = 1.4×10^2 N·m.

90. (a) Equation 10-12 leads to $\alpha = -\omega_o/t = -(25.0\text{ rad/s})/(20.0\text{ s}) = -1.25\text{ rad/s}^2$.

(b) Equation 10-15 leads to $\theta = \frac{1}{2}\omega_o t = \frac{1}{2}(25.0\text{ rad/s})(20.0\text{ s}) = 250\text{ rad}$.

(c) Dividing the previous result by 2π we obtain θ = 39.8 rev.