Ch. 8 Rotational Kinematics

Phys 131 Recitation

For Recitation Practice

Chapter 8

FOC: 3, 4, 6, 10, 13 & 15.

Problems: 1, 9, 22 & 25.

FOC 3

Section 8.2 Angular Velocity and Angular Acceleration

3. The radius of the circle traced out by the second hand on a clock is 6.00 cm. In a time *t* the tip of the second hand moves through an arc length of 24.0 cm. Determine the value of *t* in seconds.

$\theta = s/r$ = 24 cm/6 cm= 4 rad

2π rad = 60 sec

4 rad = x ?

X=38.2 sec

FOC 4

4. A rotating object has an angular acceleration of $\alpha = 0$ rad/s^2. Which one or more of the following three statements is consistent with a zero angular acceleration? A. The angular velocity is $\omega = 0$ rad/s at all times. B. The angular velocity is $\omega = 10$ rad/s at all times. C. The angular displacement θ has the same value at all times. **(a)** A, B, and C **(b)** A and B, but not C **(c)** A only **(d)** B only **(e)** C only

$$\bar{\alpha} = (\omega - \omega_0)/t$$

$$\theta = \tfrac{1}{2}(\omega_0 + \omega)t$$

4. (a) An angular acceleration of zero means that the angular velocity has the same value at all times, as in statements A or B. However, statement C is also consistent with a zero angular acceleration, because if the angular displacement does not change as time passes, then the angular velocity remains constant at a value of 0 rad/s.

FOC 6

Section 8.3 The Equations of Rotational Kinematics

6. A rotating wheel has a constant angular acceleration. It has an angular velocity of 5.0 rad/s at time $t = 0$ s, and 3.0 s later has an angular velocity of 9.0 rad/s. What is the angular displacement of the wheel during the 3.0-s interval? **(a)** 15 rad **(b)** 21 rad **(c)** 27 rad **(d)** There is not enough information given to determine the angular displacement.

6. (b) Since values are given for the initial angular velocity ω_0, the final angular velocity ω, and the time t, Equation 8.6 [$\theta = \frac{1}{2}(\omega_0 + \omega)t$] can be used to calculate the angular displacement θ.

$\theta = \frac{1}{2}(5 + 9)3 = 21$ rad

FOC 10

Section 8.4 Angular Variables and Tangential Variables

10. A merry-go-round at a playground is a circular platform that is mounted parallel to the ground and can rotate about an axis that is perpendicular to the platform at its center. The angular speed of the merry-go-round is constant, and a child at a distance of 1.4 m from the axis has a tangential speed of 2.2 m/s. What is the tangential speed of another child, who is located at a distance of 2.1 m from the axis?**(a)** 1.5 m/s **(b)** 3.3 m/s **(c)** 2.2 m/s **(d)** 5.0 m/s **(e)** 0.98 m/s

10. (b) According to Equation 8.9 ($v_T = r\omega$), the tangential speed is proportional to the radius r when the angular speed ω is constant, as it is for the merry-go-round. Thus, the angular speed of the second child is $v_T = (2.2\text{ m/s})\left(\dfrac{2.1\text{ m}}{1.4\text{ m}}\right)$.

FOC 13

Section 8.5 Centripetal Acceleration and Tangential Acceleration

13. A wheel rotates with a constant angular speed ω. Which one of the following is true concerning the angular acceleration α of the wheel, the tangential acceleration a_T of a point on the rim of the wheel, and the centripetal acceleration a_c of a point on the rim?

(a) $\alpha = 0$ rad/s^2, $a_T = 0$ m/s^2, and $a_c = 0$ m/s^2

(b) $\alpha = 0$ rad/s^2, a_T fi 0 m/s^2, and $a_c = 0$ m/s^2

(c) $\alpha \neq 0\,\text{rad/s}^2$, $a_T = 0$ m/s^2, and $a_c = 0$ m/s^2

(d) $\alpha = 0$ rad/s^2, $a_T = 0$ m/s^2, and $\alpha_c \neq 0\,\text{m/s}^2$

(e) $\alpha \neq 0\,\text{rad/s}^2$, $\alpha_T \neq 0\,\text{m/s}^2$, and $\alpha_c \neq 0\,\text{m/s}^2$

13. (d) Since the angular speed ω is constant, the angular acceleration α is zero, according to Equation 8.4. Since $\alpha = 0$ rad/s^2, the tangential acceleration a_T is zero, according to Equation 8.10. The centripetal acceleration a_c, however, is not zero, since it is proportional to the square of the angular speed, according to Equation 8.11, and the angular speed is not zero.

$$\bar{\alpha} = (\omega - \omega_0)/t = 0\,\frac{\text{rad}}{\text{s}^2}$$

FOC 15

Section 8.6 Rolling Motion

15. The radius of each wheel on a bicycle is 0.400 m. The bicycle travels a distance of 3.0 km. Assuming that the wheels do not slip, how many revolutions does each wheel make?

(a) 1.2×10^3 revolutions

(b) 2.4×10^2 revolutions

(c) 6.0×10^3 revolutions

(d) 8.4×10^{-4} revolutions

(e) Since the time of travel is not given, there is not enough information for a solution.

15. (a) The number N of revolutions is the distance s traveled divided by the circumference $2\pi r$ of a wheel: $N = s/(2\pi r)$. $= \dfrac{3\times10^3\,m}{2\pi\ 0.4m}$

Pr. 1

1. ssm A pitcher throws a curveball that reaches the catcher in 0.60 s. The ball curves because it is spinning at an average angular velocity of 330 rev/min (assumed constant) on its way to the catcher's mitt. What is the angular displacement of the baseball (in radians) as it travels from the pitcher to the catcher?

$\alpha = 0$ rad/s

$$\theta = \underbrace{\tfrac{1}{2}(\omega_0 + \omega)}\, t$$

REASONING The average angular velocity is equal to the angular displacement divided by the elapsed time (Equation 8.2). Thus, the angular displacement of the baseball is equal to the product of the average angular velocity and the elapsed time. However, the problem gives the travel time in seconds and asks for the displacement in radians, while the angular velocity is given in revolutions per minute. Thus, we will begin by converting the angular velocity into radians per second.

SOLUTION Since 2π rad = 1 rev and 1 min = 60 s, the average angular velocity $\bar{\omega}$ (in rad/s) of the baseball is

$$\bar{\omega} = \left(\frac{330\ \cancel{\text{rev}}}{\cancel{\text{min}}}\right)\left(\frac{2\pi\ \text{rad}}{1\ \cancel{\text{rev}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60\ \text{s}}\right) = 35\ \text{rad/s}$$

Since the average angular velocity of the baseball is equal to the angular displacement $\Delta\theta$ divided by the elapsed time Δt, the angular displacement is

$$\Delta\theta = \bar{\omega}\,\Delta t = (35\ \text{rad/s})(0.60\ \text{s}) = \boxed{21\ \text{rad}} \qquad (8.2)$$

Pr. 9

9. ssm A Ferris wheel rotates at an angular velocity of 0.24 rad/s. Starting from rest, it reaches its operating speed with an average angular acceleration of 0.030 rad/s^2. How long does it take the wheel to come up to operating speed?

REASONING Equation 8.4 $\left[\bar{\alpha} = \left(\omega - \cancelto{0}{\omega_0}\right)/t\right]$ indicates that the average angular acceleration is equal to the change in the angular velocity divided by the elapsed time. Since the wheel starts from rest, its initial angular velocity is $\omega_0 = 0$ rad/s. Its final angular velocity is given as $\omega = 0.24$ rad/s. Since the average angular acceleration is given as $\bar{\alpha} = 0.030 \text{ rad/s}^2$, Equation 8.4 can be solved to determine the elapsed time *t*.

SOLUTION Solving Equation 8.4 for the elapsed time gives

$$t = \frac{\omega - \omega_0}{\bar{\alpha}} = \frac{0.24 \text{ rad/s} - 0 \text{ rad/s}}{0.030 \text{ rad/s}^2} = \boxed{8.0 \text{ s}}$$

Pr. 22

22. The angular speed of the rotor in a centrifuge increases from 420 to 1420 rad/s in a time of 5.00 s. **(a)** Obtain the angle through which the rotor turns. **(b)** What is the magnitude of the angular acceleration?

REASONING We know that the final angular speed is $\omega = 1420 \text{ rad/s}$. We also that the initial angular speed is $\omega_0 = 420 \text{ rad/s}$ and that the time during which the change in angular speed occurs is $t = 5.00 \text{ s}$. With these three values, we can use $\theta = \frac{1}{2}(\omega + \omega_0)t$ (Equation 8.6) to calculate the angular displacement θ. Then, we can use $\omega = \omega_0 + \alpha t$ (Equation 8.4) to determine the angular acceleration α.

SOLUTION

a. Using Equation 8.6, we find that

$$\theta = \tfrac{1}{2}(\omega + \omega_0)t = \tfrac{1}{2}(1420 \text{ rad/s} + 420 \text{ rad/s})(5.00 \text{ s}) = \boxed{4.60 \times 10^3 \text{ rad}}$$

b. Solving Equation 8.4 for α, we find that

$$\alpha = \frac{\omega - \omega_0}{t} = \frac{1420 \text{ rad/s} - 420 \text{ rad/s}}{5.00 \text{ s}} = \boxed{2.00 \times 10^2 \text{ rad/s}^2}$$

Pr. 25

25. ssm The wheels of a bicycle have an angular velocity of +20.0 rad/s. Then, the brakes are applied. In coming to rest, each wheel makes an angular displacement of +15.92 revolutions. **(a)** How much time does it take for the bike to come to rest? **(b)** What is the angular acceleration (in rad/s^2) of each wheel?

REASONING

a. The time t for the wheels to come to a halt depends on the initial and final velocities, ω_0 and ω, and the angular displacement θ: $\theta = \frac{1}{2}(\omega_0 + \omega)t$ (see Equation 8.6). Solving for the time yields

0 rest

$$t = \frac{2\theta}{\omega_0 + \omega}$$

b. The angular acceleration α is defined as the change in the angular velocity, $\omega - \omega_0$, divided by the time t:

$$\alpha = \frac{\omega - \omega_0}{t} \qquad (8.4)$$

SOLUTION

a. Since the wheel comes to a rest, ω = 0 rad/s. Converting 15.92 revolutions to radians (1 rev = 2π rad), the time for the wheel to come to rest is

$$t = \frac{2\theta}{\omega_0 + \omega} = \frac{2(+15.92\ \cancel{\text{rev}})\left(\frac{2\pi\ \text{rad}}{1\ \cancel{\text{rev}}}\right)}{+20.0\ \text{rad/s} + 0\ \text{rad/s}} = \boxed{10.0\ \text{s}}$$

b. The angular acceleration is

$$\alpha = \frac{\omega - \omega_0}{t} = \frac{0\ \text{rad/s} - 20.0\ \text{rad/s}}{10.0\ \text{s}} = \boxed{-2.00\ \text{rad/s}^2}$$