P6.8. Strategize: The tip is in uniform circular motion. We can use known expressions to relate translational speed to frequency and to determine centripetal acceleration.

Prepare: A preliminary calculation will determine ω in rad/s.

$$\omega = 13\frac{\text{rev}}{\text{min}}\left(\frac{2\pi\ \text{rad}}{1\ \text{rev}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right) = 1.36\ \text{rad/s}$$

Solve: (a) The magnitude of the tip's velocity is displacement divided by time:

$$v = \omega r = (1.36\ \text{rad/s})(56\ \text{m}) = 76\ \text{m/s}$$

(b) The centripetal acceleration is

$$a_r = \omega^2 r = (1.36\ \text{rad/s})^2(56\ \text{m}) = 100\ \text{m/s}^2$$

Assess: What appear to be lazily rotating blades are moving quite quickly.

P7.7. Strategize: This problem involves angular displacement at a constant speed. We note that 1 rev = 2π rad = 360°.

Prepare: We'll use the equation in the text to compute the angular displacement. We are given $\theta_i = 0.45$ rad and that $\Delta t = 8.0\ \text{s} - 0\ \text{s} = 8.0\ \text{s}$.

We'll do a preliminary calculation to convert $\omega = 78$ rpm into rad/s:

$$78\ \text{rpm} = 78\frac{\text{rev}}{\text{min}}\left(\frac{2\pi\,\text{rad}}{1\ \text{rev}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right) = 8.17\ \text{rad/s}$$

Solve: Solve the equation for θ_f:

$$\begin{aligned}\theta_f &= \theta_i + \omega\,\Delta t = 0.45\ \text{rad} + (8.17\ \text{rad/s})(8.0\ \text{s}) = 65.8\ \text{rad} = 10.474\times 2\pi\ \text{rad}\\ &= 10\times 2\pi\ \text{rad} + 0.474\times 2\pi\ \text{rad} = 10\times 2\pi\ \text{rad} + 2.98\ \text{rad}\end{aligned}$$

So the speck completed almost ten and a half revolutions. An observer would say the angular position is 3.0 rad (to two significant figures) at $t = 8.0$ s.

Assess: Ask your grandparents if they remember the old records that turned at 78 rpm. They turned quite fast and so the music didn't last long before it was time to turn the record over.

Singles came on smaller records that turned at 45 rpm, and later "long play" (LP) records turned at 33 rpm.

CDs don't have a constant angular velocity, instead they are designed to have constant linear velocity, so the motor has to change speeds. For the old vinyl records the recording had to take into account the changing linear velocity because they had constant angular velocity.

P7.10. Strategize: This problem involves rotational motion at a constant speed within a given time interval. The speed does change, but quickly enough that we treat the change as being immediate.

Prepare: The angular displacement of a rotating object equals the area under the angular velocity graph. We need to convert the angular velocities from rpm to rad/s. The two which are nonzero are $10,000\text{ rpm}$ and $25,000\text{ rpm}$:

$$10,000\frac{\text{rev}}{\text{min}}=\left(10,000\frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi\text{ rad}}{1\text{ rev}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)=\frac{1000}{3}\pi\frac{\text{rad}}{\text{s}}=\text{ and}$$

$$25,000\frac{\text{rev}}{\text{min}}=\left(25,000\frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi\text{ rad}}{1\text{ rev}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)=\frac{2500}{3}\pi\frac{\text{rad}}{\text{s}}$$

Solve: (a) Since the blades are moving at a constant speed from 5 s to 15 s, we can write $\Delta t=\frac{\Delta\theta}{\omega}$. Inserting the known values, we find:

$$\Delta t=\frac{\Delta\theta}{\omega}=\frac{\pi/2\text{ rad}}{2500\pi/3\text{ rad/s}}=6.0\times10^{-4}\text{ s}$$

(b) Between 15 s and 20 s, the speed is constant, such that we can write $\Delta\theta=\omega\Delta t$. Inserting known values, we find:

$$\Delta\theta=\left(\frac{1000\pi}{3}\text{ rad/s}\right)(5.0\text{ s})=5236\text{ rad.}$$

We are asked for the number of revolutions, so we divide this number of radians by 2π to obtain

$$\Delta\theta=(5236\text{ rad})\left(\frac{1\text{ rev}}{2\pi\text{ rad}}\right)=830\text{ rev.}$$

(c) We know $v=\omega r$. Inserting given values, and using the larger of the two angular velocities we determined, we find

$$v_{\text{empty}}=\omega_{\text{empty}}r=\left(\frac{2500\pi}{3}\text{ rad/s}\right)(0.030\text{m})=79\text{ m/s.}$$

Assess: If we convert $25,000\text{ rpm}$ to units of rev/s we have about 400 rev/s. So it makes sense that the time required for just ¼ of a revolution ($90°$) would be less than 1 ms.

P7.14. Strategize: In this problem, we assume constant angular acceleration. Thus we can use the angular kinematic equations.

Prepare: Rather than using degrees, we convert $90°$ to $\pi/2$ rad. We assume the claw starts from rest and we can use $\Delta\theta = \omega_i \Delta t + \frac{1}{2}\alpha(\Delta t)^2$ and $\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$ to determine the unknowns. We can use $a = \alpha r$ and $v = \omega r$ to relate angular and linear variables.

Solve: **(a)** Using the fact that $\omega_i = 0$, we have $\Delta\theta = \frac{1}{2}\alpha(\Delta t)^2 \Rightarrow \alpha = \frac{2\Delta\theta}{(\Delta t)^2} = \frac{2(\pi/2)}{(1.3\times10^{-3}\ \text{s})^2} = 1.9\times10^6\ \text{rad/s}^2$.

(b) $\omega_f = \sqrt{2\alpha\Delta\theta} = \sqrt{2(1.86\times10^6\ \text{rad/s}^2)(\pi/2\ \text{rad})} = 2.4\times10^3\ \text{rad/s}$.

(c) We us $a = \alpha r$ to determine the tangential acceleration using part (a):

$$a = \alpha r = (1.86\times10^6\ \text{rad/s}^2)(0.015) = 2.8\times10^4\ \text{m/s}^2$$

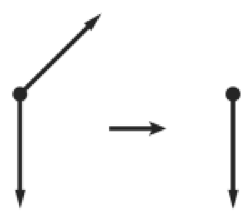
(d) We use $v = \omega r$ to determine the tangential speed using part (b):

$$v = \omega r = (2.42\times10^3\ \text{rad/s}^2)(0.015) = 36\ \text{m/s}$$

Assess: These are extremely large accelerations and speeds.

P4.7. Strategize: This problem involves forces acting on an object. A diagram will be useful.

Prepare: In drawing a free-body diagram, forces will come from objects touching the person, or from gravity. The only object interacting with the person would be the chain supporting the swing. In general, that chain does exert a force on the person (or on the seat, and then the seat exerts the force on the person). This might cause a person to draw the free body diagram shown on the left.

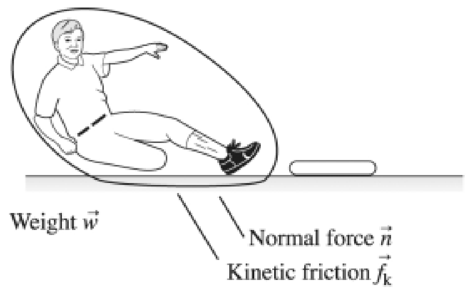


However, note that when the maximum height is reached, you can feel the chains go lax. We suspect therefore that perhaps the diagram on the right is more correct. This is considered more thoroughly below.

Solve: When a person swings, they move in a circular arc. If their speed were constant (or changing very slowly) we could determine the radial force that must be acting on them (along the direction of the chain) using $F_r = ma_r = mv^2/r$. But at the peak of the swing, the speed is momentarily zero, meaning there would be no radial force at all. This is consistent with our suspicion based on chains going lax at the maximum height. Thus the only force is gravity.

Assess: From the maximum height, the person begins accelerating downward. Only once they have non-zero speed does the tension in the chain once again play a role in curving their path into an arc.

P4.9. Strategize: Gravity can act on objects at a distance (even if the objects are not touching the Earth), but other forces discussed in this chapter require contact with the object.
Prepare: Draw a picture of the situation, identify the system, in this case the baseball player, and draw a closed curve around it. Name and label all relevant contact forces and long-range forces.



Solve: There are three forces acting *on* the baseball player due to his interactions with the two agents earth and ground. One of the forces *on* the player is the long-range weight force *by* the earth. Another force is the normal force exerted *by* the ground due to the contact between him and the ground. The third force is the kinetic friction force *by* the ground due to his sliding motion on the ground.
Assess: Note that the kinetic friction force would be *absent* if the baseball player were *not* sliding.

P4.15. Strategize: We will use the particle model for the object and use Newton's second law.
Prepare: Assume that the maximum force the road exerts on the car is the same in both cases.
Solve: Use primed quantities for the case with the four new passengers and unprimed quantities for the original case with just the driver. $F' = F$. The original mass was 1200 kg and the new mass is 1600 kg.

$$a' = \frac{F'}{m'} = \frac{F}{m'} = \frac{ma}{m'} = \frac{(1200 \text{ kg})(4 \text{ m/s}^2)}{1600 \text{ kg}} = 3.0 \text{ m/s}^2$$

Assess: We expected the maximum acceleration to be less with the passengers than with the driver only.

P4.22. Strategize: We can relate the acceleration and force using Newton's second law.
Prepare: We are given the acceleration curve and the mass. We know from $\sum \vec{F} = m\vec{a}$ that the largest acceleration corresponds to the largest sum of all forces. Thus, we simply need to apply Newton's second law to the largest acceleration in the figure.
Solve: $\left|\left(\sum \vec{F}\right)\right|_{\max} = ma_{\max} = (1650 \text{ kg})(3.0\times10^2 \text{ m/s}^2) = 5.0\times10^5 \text{ N}$
Assess: This is an extremely large force, but is reasonable for such a large acceleration.

P4.46. Strategize: Newton's third law tells us that for every action there is an equal and opposite reaction and that these forces are exerted on different objects.
Prepare: The 1.5 kg squid exerts a force on the 0.15 kg water while the water exerts a force on the squid.
Solve: (a) Use the 2nd law and consider the forces on the squid: $F = ma = (1.5 \text{ kg})(20 \text{ m/s}^2) = 30 \text{ N}$.

(b) The 3rd law says the magnitude of the force on the water is the same as the magnitude of the force on the squid: 30 N.

(c) Use the 2nd law and consider the forces on the water: $a = \dfrac{F}{m} = \dfrac{30 \text{ N}}{0.15 \text{ kg}} = 200 \text{ m/s}^2$.

Assess: Because the water had 1/10 the mass of the squid it accelerated 10 times as much under the same force.

P4.67. Strategize: Acceleration is related to force through Newton's second law.

Prepare: The agent of the force is the object from which the force originates. The force can be found using Newton's second law and the given mass of the greyhound. Finally, the distance travelled in the first 4.0 s can be found using kinematic equations, since the acceleration is constant over that interval.

Solve: **(a)** The ground is the agent of force. The greyhound exerts a force on the ground and the ground exerts a force back on the greyhound; the latter is the force that propels the greyhound forward.

(b) Assuming the force the ground exerts on the greyhound is the only force in the horizontal direction acting on the greyhound, we can write $\sum F_x = F_{\text{ground greyhound}} = ma_x = (32\text{ kg})(10\text{ m/s}^2) = 320\text{ N}$.

(c) We can use Equation 2.11, and we include the fact that the greyhounds start from rest:

$$\Delta x = (v_x)_\text{i}\Delta t + \frac{1}{2}a_x(\Delta t)^2 = \frac{1}{2}(10\text{m/s}^2)(4\text{ s})^2 = 80\text{m}.$$

Assess: This is a reasonable distance for extremely fast racing dogs.