Discussion Examples
Chapter 5: Newton's Laws of Motion

5. A 0.53-kg billiard ball initially at rest is given a speed of 12 m/s during a time interval of 4.0 ms. What average force acted on the ball during this time?

Picture the Problem: The billiard ball is accelerated along a straight line.

Strategy: Find the acceleration from the initial and final speeds and from the time interval. Use the known acceleration to find the average force on the ball by using Newton's Second Law.

Solution: Determine the acceleration from the initial and final speeds, and apply Newton's Second Law:

$$F = ma = m\frac{\Delta v}{\Delta t} = (0.53\text{ kg})\frac{(12\text{ m/s} - 0)}{4.0\times10^{-3}\text{ s} - 0} = 1600\text{ N} = \boxed{1.6\text{ kN}}$$

Insight: This substantial force (about 360 lb) acts over a very short time, so the final speed isn't all that spectacular.

12. **Stopping a 747** A 747 jetliner lands and begins to slow to a stop as it moves along the runway. If its mass is 3.50×10^5 kg, its speed is 27.0 m/s, and the net braking force is 4.30×10^5 N, **(a)** what is its speed 7.50 s later? **(b)** How far has it traveled in this time?

Picture the Problem: The 747 is accelerated horizontally in the direction opposite its motion in order to slow it down from its initial speed of 27.0 m/s.

Strategy: Use equation 5-1 to find the acceleration from the known force and mass, then use equations 2-7 and 2-10 to find the speed and distance traveled.

Solution: 1. (a) Use equation 5-1 to find $\vec{\mathbf{a}}$:

$$\vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}}{m} = \frac{(-4.30\times10^5)\hat{\mathbf{x}}\text{ N}}{3.50\times10^5\text{ kg}} = (-1.23\text{ m/s}^2)\hat{\mathbf{x}}$$

2. Use equation 2-7 to find the final speed:

$$v = v_0 + at = 27.0\text{ m/s} + (-1.23\text{ m/s}^2)(7.50\text{ s}) = \boxed{17.8\text{ m/s}}$$

3. (b) Use equation 2-10 to find the distance traveled by the 747 as it slows down:

$$\Delta x = \tfrac{1}{2}(v_0 + v)\Delta t = \tfrac{1}{2}(27.0 + 17.8\text{ m/s})(7.50\text{ s}) = \boxed{168\text{ m}}$$

Insight: The landing speed of a Boeing 747-200 is 71.9 m/s (161 mi/h) and it has a specified landing roll distance of 2,121 m, requiring an average landing acceleration of -1.22 m/s^2.

14. **CP** • **Predict/Explain** A small car collides with a large truck. **(a)** Is the magnitude of the force experienced by the car greater than, less than, orequal to the magnitude of the force experienced by the truck? **(b)** Choose the *best* explanation from among the following:
I. Action-reaction forces always have equal magnitude.
II. The truck has more mass, and hence the force exerted on it is greater.
III. The massive truck exerts a greater force on the lightweight car.

Picture the Problem: A small car collides with a large truck.

Strategy: Consider Newton's Laws of motion when answering the conceptual question.

Solution: 1. (a) Newton's Third Law states that when the car exerts a force on the truck, the truck exerts an equal and opposite force on the car. We conclude that the magnitude of the force experienced by the car is $\boxed{\text{equal to}}$ the magnitude of the force experienced by the truck.

2. (b) The best explanation is $\boxed{\text{I. Action-reaction forces always have equal magnitude}}$. Statements II and III are both false.

Insight: The force has a larger effect (produces a larger acceleration) on the smaller car due to its smaller inertia.

27. A shopper pushes a 7.5-kg shopping cart up a 13° incline, as shown in **Figure 5–22**. Find the magnitude of the horizontal force, $\vec{\mathbf{F}}$, needed to give the cart an acceleration of 1.41 m/s^2.

Picture the Problem: The cart is pushed partly into the incline and partly up the incline by the pushing force $\vec{\mathbf{F}}$, as shown in the figure at right.

Strategy: Write Newton's Second Law for the *x* direction, where $\hat{\mathbf{x}}$ points up the incline and parallel to it. Solve the resulting equation for the magnitude of $\vec{\mathbf{F}}$.

Solution: The component of the force pushing up the incline is $F\cos\theta$ and the component of the weight pushing down the incline is $mg\sin\theta$:

$$\sum F_x = F\cos\theta - mg\sin\theta = ma$$

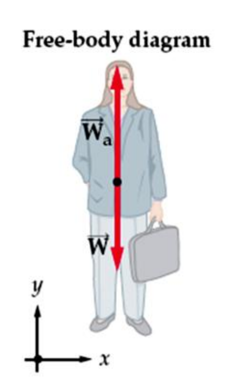
$$F = \frac{ma + mg\sin\theta}{\cos\theta} = \frac{(7.5\text{ kg})\left[1.41 + (9.81\text{ m/s}^2)\sin 13°\right]}{\cos 13°}$$

$$F = \boxed{28\text{ N}}$$

Insight: They'd better offer double coupons at this store, because a 13° incline is a 23% grade; danger territory for over-the-road truckers and a lot of extra work for the average grocery shopper!

40. **IP** As part of a physics experiment, you stand on a bathroom scale in an elevator. Though your normal weight is 610 N, the scale at the moment reads 730 N. **(a)** Is the acceleration of the elevator upward, downward, or zero? Explain. **(b)** Calculate the magnitude of the elevator's acceleration. **(c)** What, if anything, can you say about the velocity of the elevator? Explain.

Picture the Problem: The elevator accelerates up and down, changing your apparent weight W_a. A free body diagram of the situation is depicted at right.



Strategy: There are two forces acting on you: the applied force $\vec{\mathbf{F}} = \vec{\mathbf{W}}_a$ of the scale acting upward and the force of gravity $\vec{\mathbf{W}}$ acting downward. The force W_a represents your apparent weight because it is both the force the scale exerts on you and the force you exert on the scale. Use Newton's Second Law together with the known force W_a acceleration to determine the acceleration *a*.

Solution: 1. (a) The direction of acceleration is $\boxed{\text{upward}}$. An upward acceleration results in an apparent weight greater than the actual weight.

2. (b) Use Newton's Second Law together with the known forces to determine the acceleration *a*.

$$\sum F_y = W_a - W = ma$$

$$a = \frac{W_a - W}{m} = \frac{W_a - W}{W/g} = \frac{730 - 610\text{ N}}{610\text{ N}}\left(9.81\text{ m/s}^2\right) = \boxed{1.9\text{ m/s}^2}$$

3. (c) The only thing we can say about the velocity is that it is changing in the upward direction. That means $\boxed{\text{the elevator is either speeding up if it is traveling upward, or slowing down if it is traveling downward}}$.

Insight: You feel the effects of apparent weight twice for each ride in an elevator, once as it accelerates from rest and again when it slows down and comes to rest.

63. **IP BIO Grasshopper Liftoff** To become airborne, a 2.0-g grasshopper requires a takeoff speed of 2.7 m/s. It acquires this speed by extending its hind legs through a distance of 3.7 cm. **(a)** What is the average acceleration of the grasshopper during takeoff? **(b)** Find the magnitude of the average net force exerted on the grasshopper by its hind legs during takeoff. **(c)** If the mass of the grasshopper increases, does the takeoff acceleration increase, decrease, or stay the same? **(d)** If the mass of the grasshopper increases, does the required takeoff force increase, decrease, or stay the same? Explain.

Picture the Problem: The grasshopper is accelerated along a straight line by the force generated by its hind legs.

Strategy: Use equation 2-12 to find the acceleration of the grasshopper, and then use Newton's Second Law to find the magnitude of the average net force.

Solution: 1. (a) Find the acceleration of the grasshopper using equation 2-12:

$$a = \frac{v^2 - v_0^{\,2}}{2\Delta x} = \frac{(2.7\text{ m/s})^2 - 0^2}{2(0.037\text{ m})} = \boxed{99\text{ m/s}^2}$$

2. (b) Apply Newton's Second Law to find F_{legs}:

$$\sum F_y = F_{\text{legs}} - mg = ma$$
$$F_{\text{legs}} = m(a+g) = (0.0020\text{ kg})(99 + 9.81\text{ m/s}^2) = \boxed{0.22\text{ N}}$$

3. (c) As long as the final speed and acceleration distance remain unchanged, the takeoff acceleration will $\boxed{\text{stay the same}}$ even though the mass increases, because the acceleration is independent of mass.

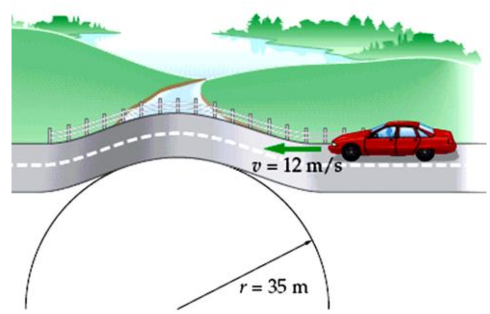
4. (d) If the mass of the grasshopper increases, the required takeoff force will $\boxed{\text{increase}}$ because there is more inertia.

Insight: The force generated by the grasshopper's legs is more likely to stay the same as the mass of the grasshopper increases, so that its takeoff acceleration will decrease and it won't be able to jump as far.

Chapter 6: Applications of Newton's Laws

62. Driving in your car with a constant speed of 12 m/s, you encounter a bump in the road that has a circular cross-section, as indicated in **Figure 6–35**. If the radius of curvature of the bump is 35 m, find the apparent weight of a 67-kg person in your car as you pass over the top of the bump.

Picture the Problem: The car follows a circular path at constant speed as it passes over the bump.



Strategy: The centripetal acceleration is downward, toward the center of the circle, as the car passes over the bump. Write Newton's Second Law in the vertical direction and solve for the normal force *N*, which is also the apparent weight of the passenger.

Solution: 1. Write Newton's Second Law for the passenger and solve for *N*:

$$\sum F_y = N - mg = -ma_{\text{cp}} = -mv^2/r$$
$$N = m(g - v^2/r)$$

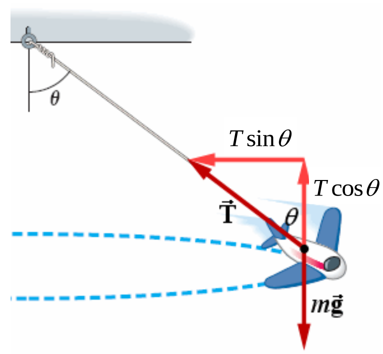
2. Insert numerical values:

$$N = (67\text{ kg})\left[9.81\text{ m/s}^2 - \frac{(12\text{ m/s})^2}{35\text{ m}}\right] = 380\text{ N} = \boxed{0.38\text{ kN}}$$

Insight: This apparent weight is 42% less than the normal 0.66-kN weight of the passenger.

85. **A Conical Pendulum** A 0.075-kg toy airplane is tied to the ceiling with a string. When the airplane's motor is started, it moves with a constant speed of 1.21 m/s in a horizontal circle of radius 0.44 m, as illustrated in **Figure 6–38**. Find **(a)** the angle the string makes with the vertical and **(b)** the tension in the string.

Picture the Problem: The free-body diagram of the airplane is depicted at right.



Strategy: Let the x axis point horizontally from the airplane toward the center of its circular motion, and let the y axis point straight upward. Write Newton's Second Law in both the horizontal and vertical directions and use the resulting equations to find θ and the tension T.

Solution: 1. (a) Write Newton's Second Law in the x and y directions:

$$\sum F_x = T\sin\theta = ma_{\text{cp}} = mv^2/r$$
$$\sum F_y = T\cos\theta - mg = 0$$

2. Solve the y equation for T and substitute the result into the x equation, and solve for θ:

$$T = mg/\cos\theta$$
$$T\sin\theta = \left(\frac{mg}{\cos\theta}\right)\sin\theta = mv^2/r$$
$$\tan\theta = v^2/rg$$
$$\theta = \tan^{-1}\left[\frac{(1.21\text{ m/s})^2}{(0.44\text{ m})(9.81\text{ m/s}^2)}\right] = \boxed{19°}$$

3. (b) Calculate the tension from the equation in step 2:

$$T = \frac{mg}{\cos\theta} = \frac{(0.075\text{ kg})(9.81\text{ m/s}^2)}{\cos 19°} = \boxed{0.78\text{ N}}$$

Insight: This airplane is pretty small. The toy weighs only 0.74 N = 2.6 ounces and flies in a circle of diameter 2.9 ft.