Chapter 5

Newton's Laws of Motion

Answers to Even-numbered Conceptual Questions

2. As the dog shakes its body, it starts water in its fur moving in one direction. When it then begins to shake its body in the opposite direction, much of the water continues in the same direction – due to the law of inertia (Newton's first law). As a result, water leaves the fur with each reversal in direction.

4. If the tablecloth is pulled rapidly, it can exert a force on the place settings for only a very short time. In this brief time, the objects on the table accelerate, but only slightly. Therefore, the objects may have barely moved by the time the tablecloth is completely removed.

6. The drag racer needs an engine to turn the wheels, which makes them push against the ground. It is only in this way that the ground is able to exert a reaction force on the car.

8. The astronaut should push the jet pack away from him, in the opposite direction from the spaceship. As a result, the reaction force exerted on him by the pack will accelerate him toward the ship.

10. The action-reaction forces are the force exerted on the ball by the bat, and the force exerted on the bat by the ball. The force exerted on the ball causes it to change its direction of motion and move into the field of play (hopefully). The force exerted on the bat slows its forward motion.

12. The forces between the two cars are an action-reaction pair; therefore, the forces have exactly the same magnitude. The effect of the forces is quite different, however. In particular, the car with the smaller mass experiences a greater acceleration than the car with the larger mass. This could increase the chance of injury for the occupants of the smaller car.

14. The floor exerts an upward force on the ball that causes it to rebound to your hand.

16. To cause a deceleration, the upward force exerted on you by the parachute must be greater in magnitude than your weight. In this case, the net force acting on you is upward, as is your acceleration. Since your acceleration and velocity are in different directions, you will decelerate. See Figure 2-11 for further details.

18. The whole brick also experiences twice the *force* due to gravity. As a result, these two effects (more inertia, more force) exactly cancel, and the free fall acceleration is independent of mass.

20. No. If only a single force acts on the object, it will not stay at rest; instead, it will accelerate in the direction of the force.

22. Object 1 has the greater net force acting on it, due to its larger mass. Therefore, object 1 reaches the ground first.

24. Yes. In the upwardly accelerating elevator it is as if you are playing a game of darts on a planet with a greater acceleration of gravity. Therefore, you must aim higher than you would if the elevator were moving upward with constant speed.

26. **(a)** When the parrot jumps, it pushes down on its perch. In this case, the scale reads a larger value. **(b)** When the parrot is in the air, the scale reads only the weight of the bird cage. **(c)** When the parrot lands, the perch exerts an upward force on it to bring it to rest. As a result, the scale reads again reads a larger value. The average of the scale readings in parts (a), (b), and (c) is just the weight of the parrot plus the weight of the bird cage.

28. As you hit the rug with the tennis racket, you cause it to accelerate rapidly. The dust on the rug, if it is not attached too firmly, will be left behind as the rug accelerates away from it. In this way, you are able to remove much of the dust from the rug.

30. To bring the bowling ball to rest, you must exert an upward force on it that is greater than its weight. This takes some effort, and the force you exert may be only slightly more than the ball's weight. As a result, it takes a considerable distance to bring the ball to a stop. This isn't a problem if you catch the ball at chest level. If you try this with your hands a half inch above the ground, however, you won't be able to stop the ball before your hand is smashed into the floor.

32. Consider a projectile that moves with no air resistance. At the top of its flight, it moves horizontally while the net force acting on it – gravity – acts in the vertical direction.

34. Yes, it would still hurt. The reason is that even though the bucket is "weightless", it still has nonzero mass. Therefore, it has inertia, and when it is kicked it will resist having its state of motion changed. The way it resists a change in its motion is by exerting an equal-but-opposite reaction force on the object trying to make the change; in this case, your foot. This is the force that can make kicking the bucket painful.

Solutions to Problems

1. Find the net force.

$$\sum \vec{\mathbf{F}} = (-40.0\text{ N})\hat{\mathbf{y}} + (46.2\text{ N})\hat{\mathbf{y}} = (+6.2\text{ N})\hat{\mathbf{y}}$$

$$\vec{\mathbf{a}} = \frac{\sum \vec{\mathbf{F}}}{m} = \frac{(6.2\text{ N})\hat{\mathbf{y}}}{5.00\text{ kg}} = \boxed{(1.2\text{ m/s}^2)\hat{\mathbf{y}}}$$

2. $$\vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}}{m} = \frac{(14.0\text{ N})\hat{\mathbf{x}}}{12.5\text{ kg}} = \left(1.12\ \frac{\text{m}}{\text{s}^2}\right)\hat{\mathbf{x}}$$

$$\Delta x = \frac{1}{2}a\Delta t^2 = \frac{1}{2}\left(1.12\ \frac{\text{m}}{\text{s}^2}\right)(3.00\text{ s})^2 = \boxed{5.04\text{ m}}$$

3. $$m_{\text{Total}} = \frac{F}{a} = \frac{110\text{ N}}{2.5\ \frac{\text{m}}{\text{s}^2}} = 44\text{ kg}$$

$$m_{\text{sister}} = m_{\text{Total}} - m_{\text{sled}} = 44\text{ kg} - 7.0\text{ kg} = \boxed{37\text{ kg}}$$

4. $$F = ma = m\frac{\Delta v}{\Delta t} = (0.53\text{ kg})\frac{\left(12\ \frac{\text{m}}{\text{s}} - 0\right)}{(4.0\times 10^{-3}\text{ s}-0)} = \boxed{1.6\text{ kN}}$$

5. $a = \dfrac{v^2 - v_0^2}{2\Delta x}$

$$F = ma = m\left(\frac{v^2 - v_0^2}{2\Delta x}\right) = (92\text{ kg})\left[\frac{\left(12\ \frac{\text{m}}{\text{s}}\right)^2 - 0}{2(25\text{ m}-0)}\right] = \boxed{260\text{ N}}$$

6. (a) Determine the net acceleration on the parachutist.

$${v_y}^2 - {v_{0y}}^2 = 2a\Delta y$$

$$a = \frac{{v_y}^2 - {v_{0y}}^2}{2\Delta y} = \frac{0 - \left(3.85\ \frac{\text{m}}{\text{s}}\right)^2}{2(0 - 0.750\text{ m})} = 9.88\ \frac{\text{m}}{\text{s}^2}$$

The force exerted on the parachutist by the ground is $F = ma = (42.0\text{ kg})\left(9.88\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{415\text{ N}}$.

(b) If the parachutist comes to rest in a shorter distance, the acceleration will be greater and the force will therefore be $\boxed{\text{greater}}$.

7. (a) Determine the average acceleration.

$$v^2 = v_0^2 + 2a_{\text{av}}\Delta x$$

$$a_{\text{av}} = \frac{v^2 - v_0^2}{2\Delta x}$$

Find the force.

$$F_{\text{av}} = ma_{\text{av}} = m\left(\frac{v^2 - v_0^2}{2\Delta x}\right) = (0.15\text{ kg})\left[\frac{\left(98\ \frac{\text{mi}}{\text{h}}\right)^2 - 0}{2(1.5\text{ m})}\right]\left(\frac{1609\text{ m}}{\text{mi}}\right)^2\left(\frac{1\text{ h}}{3600\text{ s}}\right)^2 = \boxed{96\text{ N}}$$

(b) If the mass of the ball is increased, the force must be $\boxed{\text{increased}}$ to result in the same acceleration.

8. Find the average acceleration.

$$a_{\text{av}} = \frac{v^2 - v_0^2}{2\Delta x}$$

Determine the mass.

$$m = \frac{F}{a} = F\left(\frac{2\Delta x}{v^2 - v_0^2}\right) = (803\text{ N})\left[\frac{2(0-0.15\text{ m})}{0-\left(92\ \frac{\text{mi}}{\text{h}}\right)^2}\right]\left(\frac{1\text{ mi}}{1609\text{ m}}\right)^2\left(\frac{3600\text{ s}}{\text{h}}\right)^2 = \boxed{0.14\text{ kg}}$$

9. (a)

$$\begin{aligned}\vec{\mathbf{F}} &= m\vec{\mathbf{a}}\\ &= m\frac{\Delta\vec{\mathbf{v}}}{\Delta t}\\ &= (950\text{ kg})\frac{\left(9.50\ \frac{\text{m}}{\text{s}} - 16.0\ \frac{\text{m}}{\text{s}}\right)}{(1.20\text{ s}-0)}\hat{\mathbf{x}}\\ &= (950\text{ kg})\left(-5.42\ \frac{\text{m}}{\text{s}^2}\hat{\mathbf{x}}\right)\\ &= (-5.1\text{ kN})\hat{\mathbf{x}}\\ &= \boxed{5.1\text{ kN opposite to the direction of motion}}\end{aligned}$$

(b) $\Delta x = \dfrac{v^2 - v_0{}^2}{2a} = \dfrac{\left(9.50\ \frac{\text{m}}{\text{s}}\right)^2 - \left(16.0\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-5.42\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{15.3\ \text{m}}$

10. (a) Determine the acceleration.

$$a = \frac{F}{m} = \frac{-4.30\times10^5\ \text{N}}{3.50\times10^5\ \text{kg}} = -1.23\ \frac{\text{m}}{\text{s}^2}$$

Find the speed.

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

(b) $\Delta x = \dfrac{v^2 - v_0{}^2}{2a} = \dfrac{\left(17.8\ \frac{\text{m}}{\text{s}}\right)^2 - \left(27.0\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-1.23\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{168\ \text{m}}$

11. (a) Convert the speeds.

$$\left(\frac{212\ \text{mi}}{\text{h}}\right)\left(\frac{1609\ \text{m}}{\text{mi}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 94.75\ \frac{\text{m}}{\text{s}}$$

$$\left(\frac{40.0\ \text{mi}}{\text{h}}\right)\left(\frac{1609\ \text{m}}{\text{mi}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 17.88\ \frac{\text{m}}{\text{s}}$$

Determine the acceleration.

$$a = \frac{v^2 - v_0^2}{2\Delta x} = \frac{\left(17.88\ \frac{\text{m}}{\text{s}}\right)^2 - \left(94.75\ \frac{\text{m}}{\text{s}}\right)^2}{2(165\ \text{m} - 0)} = -26.24\ \frac{\text{m}}{\text{s}^2}$$

Find the force.

$$F = ma = (885\ \text{kg})\left(-26.24\ \frac{\text{m}}{\text{s}^2}\right) = -23.2\ \text{kN}$$

(b) The strategy is to determine the acceleration from the speeds and displacement and then determine the force from the acceleration and mass.

12. (a) There are two forces acting on the brick.

(b) The forces acting on the brick are due to gravity and your hand.

(c) Yes, these forces are equal and opposite, because the brick remains at rest.

(d) No, these forces are not an action-reaction pair, because they are acting on the same object.

13. (a) There are two forces acting on the brick.

(b) The forces acting on the brick are due to gravity and your hand.

(c) No, these forces are not equal and opposite, because the brick accelerates.

(d) No, these forces are not an action-reaction pair.

14. m = mass of the trailer
M = mass of the car

(a) The trailer is accelerating at 1.90 m/s^2, so

$$F_{\text{net}} = ma = (540\text{ kg})\left(1.90\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{1.0\text{ kN}}$$

(b) The car exerts a force of 1.0 kN on the trailer. The trailer exerts an equal and opposite force on the car. The trailer exerts a net force of $\boxed{1.0\text{ kN}}$ on the car.

(c) The wheels of the car push against the ground with a force that accelerates the car and trailer. The ground pushes back with an equal and opposite force. The net force on the car is

$$F_{\text{net}} = (m+M)a - ma = Ma = (1300\text{ kg})\left(1.90\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{2.5\text{ kN}}$$

15. **(a)** The force experienced by the child is the $\boxed{\text{same}}$ as the force experienced by the parent.

(b) The acceleration of the child is $\boxed{\text{more than}}$ the acceleration of the parent. The child, who has less mass than the parent, must have a larger acceleration to keep the forces equal.

(c)

$$\begin{aligned} m_{\text{child}} a_{\text{child}} &= m_{\text{parent}} a_{\text{parent}} \\ a_{\text{parent}} &= \frac{m_{\text{child}}}{m_{\text{parent}}} a_{\text{child}} \\ &= \left(\frac{16\text{ kg}}{64\text{ kg}}\right)\left(2.6\ \frac{\text{m}}{\text{s}^2}\right) \\ &= \boxed{0.65\ \text{m/s}^2} \end{aligned}$$

16. The boxes accelerate together:

$$\begin{aligned} F &= (m_1 + m_2 + m_3)a \\ a &= \frac{F}{m_1 + m_2 + m_3} \\ &= \frac{7.50\text{ N}}{1.30\text{ kg} + 3.20\text{ kg} + 4.90\text{ kg}} \\ &= 0.7979\frac{\text{m}}{\text{s}^2} \end{aligned}$$

(a) The contact force $F_{1,2}$ accelerates boxes 2 and 3.

$$F_{1,2} = (m_2 + m_3)a = (3.20\text{ kg} + 4.90\text{ kg})\left(0.7979\frac{\text{m}}{\text{s}^2}\right) = \boxed{6.46\text{ N}}$$

(b) The contact force $F_{2,3}$ accelerates box 3.

$$F_{2,3} = m_3 a = (4.90\text{ kg})\left(0.7979\frac{\text{m}}{\text{s}^2}\right) = \boxed{3.91\text{ N}}$$

17. The boxes accelerate together.

$$F = (m_1 + m_2 + m_3)a$$
$$a = \frac{F}{m_1 + m_2 + m_3} = \frac{7.50\,\text{N}}{1.30\,\text{kg} + 3.20\,\text{kg} + 4.90\,\text{kg}} = 0.7979\,\frac{\text{m}}{\text{s}^2}$$

(a) The contact force $F_{2,1}$ accelerates box 1.

$$F_{2,1} = m_1 a = (1.30\,\text{kg})\left(0.7979\,\frac{\text{m}}{\text{s}^2}\right) = \boxed{1.04\,\text{N}}$$

(b) The contact force $F_{3,2}$ accelerates boxes 1 and 2.

$$F_{3,2} = (m_1 + m_2)a = (1.30\text{ kg} + 3.20\text{ kg})\left(0.7979\,\frac{\text{m}}{\text{s}^2}\right) = \boxed{3.59\,\text{N}}$$

18. **(a)** Find the acceleration of the two boxes due to the horizontal force.

$$a = \frac{F}{m_{\text{Total}}} = \frac{5.0\text{ N}}{5.2\text{ kg}+7.4\text{ kg}} = 0.397\,\frac{\text{m}}{\text{s}^2}$$

Since the horizontal force is applied to the lighter box, we can determine the contact force by finding the net horizontal force acting on the heavier box.

$$F = ma = (7.4\text{ kg})\left(0.397\,\frac{\text{m}}{\text{s}^2}\right) = \boxed{2.9\text{ N}}$$

(b) When the horizontal force is applied to the heavier box, the contact force is $\boxed{\text{less than}}$ that which results from the horizontal force being applied to the lighter box. Since the acceleration is the same in each case, the difference in masses results in different contact forces.

(c) $F = ma = (5.2\text{ kg})\left(0.397\,\frac{\text{m}}{\text{s}^2}\right) = \boxed{2.1\text{ N}}$

19. The incline is 26°, so the force exerted by the tractor on the trailer is

$$F = mg\sin\theta = (4300\text{ kg})\left(9.81\,\frac{\text{m}}{\text{s}^2}\right)\sin 26° = \boxed{18\text{ kN}}$$

20. Find the angle of inclination such that $a = g\sin\theta = 3.25\text{ m/s}^2$.

$$\sin\theta = \frac{a}{g}$$
$$\theta = \sin^{-1}\left(\frac{3.25\,\frac{\text{m}}{\text{s}^2}}{9.81\,\frac{\text{m}}{\text{s}^2}}\right) = \boxed{19.3°}$$

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

$$F = \frac{m(a + g\sin\theta)}{\cos\theta} = \frac{(7.5\text{ kg})\left[1.41\ \frac{\text{m}}{\text{s}^2} + \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\sin 13°\right]}{\cos 13°} = \boxed{28\text{ N}}$$

22. Place the x-axis along the forward direction of the boat. Find the force F, such that the net force in the y-direction is zero.

$$F_{y,\ 1\text{ net}} = F_1\sin\theta_1 + F\sin\theta = 0$$

$$F = \frac{-F_1\sin\theta_1}{\sin\theta} = \frac{-(130\text{ N})\sin 34°}{\sin(-45°)} = \boxed{100\text{ N}}$$

23. $F = (m_{\text{sled}} + m_{\text{child}})a = (22.7\text{ kg})a$

and

$F = 2(55\text{ N})\cos 35° - 57\text{ N} = 33.1\text{ N}$

so,

$$a = \frac{F}{m_{\text{sled}} + m_{\text{child}}} = \frac{33.1\text{ N}}{22.7\text{ kg}} = \boxed{1.5\text{ m/s}^2}$$

24. **(a)** $\sum F_y = 0$

$2(290\text{ N})\cos 24° + N - mg = 0$

$$N = mg - 2(290\text{ N})\cos 24° = (67\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right) - 2(290\text{ N})\cos 24° = \boxed{130\text{ N}}$$

(b) It would be $\boxed{\text{greater}}$ because the vertical component of the force applied through the arms is reduced as the angle with the vertical is increased.

25. **(a)** The net force on the skier results in the skier's motion. This motion is parallel to the slope, thus the direction of the net force is also parallel to the slope.

$$F = mg\sin\theta = (65\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\sin 22° = 240\text{ N}$$

$$\vec{\mathbf{F}} = \boxed{240\text{ N, downhill, parallel to the slope}}$$

(b) As the slope becomes steeper, the net force $\boxed{\text{increases}}$. As the incline increases, $\sin\theta$ approaches 1. In this case, the skier is falling. As the incline decreases, $\sin\theta$ approaches zero and the skier is standing still. In this case, the force of gravity is counteracted by the force of the ground on the skier.

26. Since the object moves with constant velocity, the net force acting on the object is zero.

$\vec{\mathbf{F}}_{\text{net}} = \mathbf{0}$

$F_{x,\text{net}} = F_x + 6.5\text{ N} = 0$

$F_x = -6.5\text{ N}$

$F_{y,\text{net}} = F_y - 4.4\text{ N} = 0$

$F_y = 4.4\text{ N}$

$\vec{\mathbf{F}} = -6.5\text{ N}\ \hat{\mathbf{x}} + 4.4\text{ N}\ \hat{\mathbf{y}}$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{4.4\text{ N}}{-6.5\text{ N}}\right) = -34° + 180° = \boxed{146°}$$

$$F = \sqrt{F_x^{\ 2} + F_y^{\ 2}} = \sqrt{(-6.5\text{ N})^2 + (4.4\text{ N})^2} = \boxed{7.8\text{ N}}$$

27. After the last car breaks free, it will continue in the direction of the train until the force of gravity brings it to rest (and then pulls it downhill).
The acceleration due to gravity is

$$a = -g\sin\theta = -\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\sin 3.2° = -0.548\ \frac{\text{m}}{\text{s}^2}$$

Determine the time.

$$t = \frac{v - v_0}{a} = \frac{0 - 3.55\ \frac{\text{m}}{\text{s}}}{-0.548\ \frac{\text{m}}{\text{s}^2}} = \boxed{6.5\ \text{s}}$$

28. The acceleration due to gravity is

$$a = -g\sin\theta = -\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\sin 3.2° = -0.548\ \frac{\text{m}}{\text{s}^2}$$

The time it takes for the car to come to rest is

$$t = \frac{v - v_0}{a} = \frac{0 - 3.55\ \frac{\text{m}}{\text{s}}}{-0.548\ \frac{\text{m}}{\text{s}^2}} = 6.48\ \text{s}$$

The distance traveled during this time is

$$x = v_0 t + \frac{1}{2}at^2 = \left(3.55\ \frac{\text{m}}{\text{s}}\right)(6.48\ \text{s}) + \frac{1}{2}\left(-0.548\ \frac{\text{m}}{\text{s}^2}\right)(6.48\ \text{s})^2 = \boxed{11\ \text{m}}$$

29. $ma = F - mg$
$F = m(a + g)$

$$a + g = 0.725\ \frac{\text{m}}{\text{s}^2} + 9.81\ \frac{\text{m}}{\text{s}^2} = 10.54\ \frac{\text{m}}{\text{s}^2}$$

(a) $m = \dfrac{F}{a+g} = \dfrac{115\ \text{N}}{10.54\ \frac{\text{m}}{\text{s}^2}} = \boxed{10.9\ \text{kg}}$

(b) $W = mg = (10.9\ \text{kg})\left(9.81\ \dfrac{\text{m}}{\text{s}^2}\right) = \boxed{107\ \text{N}}$

30. Three examples of objects weighing 1 N are: [an apple, 100 pennies, and 6 oz of soda].

31. $ma = F - mg$
$F = m(a + g)$

$$a + g = 32\ \frac{\text{m}}{\text{s}^2} + 9.81\ \frac{\text{m}}{\text{s}^2} = 41.8\ \frac{\text{m}}{\text{s}^2}$$

$$W_{\text{app}} = m(a + g) = (85\ \text{kg})\left(41.8\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{3.6\ \text{kN}}$$

32. (a) $\sum F_y = W_\text{a} - W = ma$

$$a = \frac{W_\text{a} - W}{m} = \frac{W_\text{a} - W}{\frac{W}{g}} = \left(\frac{225\ \text{lb} - 182\ \text{lb}}{182\ \text{lb}}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{2.3\ \text{m/s}^2}$$

(b) $\sum F_y = W_\text{a} - W = -ma$

$$a = \frac{W - W_\text{a}}{m} = \frac{W - W_\text{a}}{\frac{W}{g}} = \left(\frac{182\text{ lb} - 138\text{ lb}}{182\text{ lb}}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{2.4\ \text{m/s}^2}$$

33. (a) The fruit is falling with constant speed, therefore the net force on it is zero.

$\vec{\mathbf{F}} = \vec{\mathbf{F}}_\text{air} + \vec{\mathbf{F}}_\text{g} = 0$

$$F_\text{air} = -F_g = mg = (0.00121\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{0.0119\text{ N}}$$

(b) The force of air resistance is the $\boxed{\text{same}}$. Motion with constant velocity implies no net force.

34. $\sum F_y = W_\text{a} - W = -ma$

$$a = \frac{W - W_\text{a}}{m} = \frac{W - W_\text{a}}{\frac{W}{g}} = \left(\frac{W - W_\text{a}}{W}\right)g = \left(\frac{161\text{ lb} - 142\text{ lb}}{161\text{ lb}}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{1.2\ \text{m/s}^2}$$

A downward acceleration of the elevator results in an apparent weight less than your actual weight, therefore the elevator accelerates 1.2 m/s^2 $\boxed{\text{downward}}$.

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

(b) $\sum F_y = W_\text{a} - W = ma$

$$a = \frac{W_\text{a} - W}{m} = \frac{W_\text{a} - W}{\frac{W}{g}}$$

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

36. (a) $W = mg =$ actual weight

$W_1 = mg + ma = 82\text{ N}$

$W_2 = mg + 2ma = 92\text{ N}$

$2W_1 - W_2 = mg = W$

$W = 2(82\text{ N}) - (92\text{ N}) = \boxed{72\text{ N}}$

(b) $m = \frac{W}{g} = \frac{72\text{ N}}{9.81\ \frac{\text{m}}{\text{s}^2}} = 7.34\text{ kg}$

$W_1 = mg + ma$

$$a = \frac{W_1}{m} - g$$

$$= \frac{82\text{ N}}{7.34\text{ kg}} - 9.81\ \frac{\text{m}}{\text{s}^2}$$

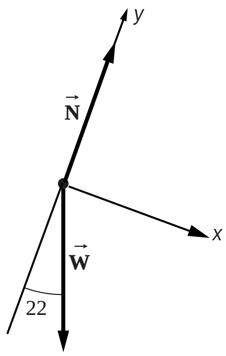
$$= \boxed{1.4\ \text{m/s}^2}$$

37. $\sum F_y = N_y + W_y + F\sin\theta = 0$

$$0 = F\sin\theta + N - mg$$

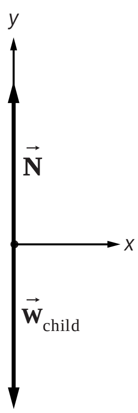
$$F = \frac{-N + mg}{\sin\theta} = \frac{-180\text{ N} + (23\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)}{\sin 25°} = \boxed{110\text{ N}}$$

38. (a)



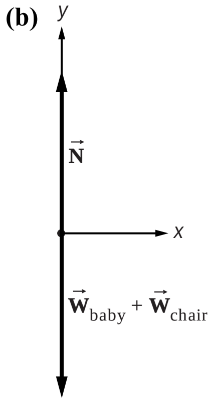
(b) $N = mg\cos\theta = (65\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\cos 22° = \boxed{590\text{ N}}$

39. (a)



$$N = mg = (9.3\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{91\text{ N}}$$

(b)



$$N = \left(m_{\text{baby}} + m_{\text{chair}}\right)g = (9.3\text{ kg} + 3.7\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{130\text{ N}}$$

40. $F\sin\theta + N - mg = 0$

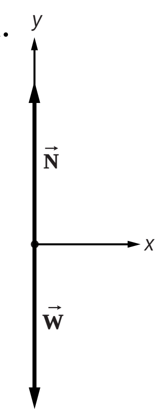
$$F = \frac{mg - N}{\sin\theta}$$

(a) $F = \dfrac{mg - \frac{mg}{2}}{\sin 90^\circ} = \boxed{\dfrac{mg}{2}}$

(b) $F = \dfrac{mg - 0}{\sin 90^\circ} = \boxed{mg}$

(c) $F = \dfrac{mg - 0}{\sin 30^\circ} = \boxed{2mg}$

41.



The free-body diagram does not change. A constant velocity implies zero acceleration (zero force).

42. **(a)** $\sum F_y = N_y + W_y = 0$

$$0 = N - mg\cos\theta$$
$$N = mg\cos\theta$$
$$= (2.7\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\cos 32°$$
$$= \boxed{22\text{ N}}$$

(b) The normal force will $\boxed{\text{increase}}$ because as the angle decreases cos θ approaches one (and N approaches mg).

43. **(a)** $\sum F_y = W_y - F\sin\theta + N_y = 0$

$$0 = N - mg - F\sin\theta$$
$$N = mg + F\sin\theta$$
$$= (18\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right) + (209\text{ N})\sin 32°$$
$$= \boxed{290\text{ N}}$$

(b) The normal force $\boxed{\text{increases}}$ because $\sin\theta$ increases.

44.

$$N = mg\ \cos\theta$$
$$\frac{mg}{2} = mg\cos\theta$$
$$\cos\theta = -\frac{1}{2}$$
$$\theta = \boxed{60°}$$

45. Determine the average acceleration.

$$a = \frac{v^2 - v_0{}^2}{2\Delta x}$$

Use a to find the average force.

$$F = ma = m\left(\frac{v^2 - v_0{}^2}{2\Delta x}\right) = (0.070\text{ kg})\left[\frac{\left(35\ \frac{\text{m}}{\text{s}}\right)^2 - 0}{2(0.80\text{ m}–0)}\right] = \boxed{54\text{ N}}$$

46. Determine the swimmer's deceleration.

$$a = \frac{v^2 - v_0{}^2}{2\Delta x} = \frac{0 - \left(1.75\ \frac{\text{m}}{\text{s}}\right)^2}{2(2.00\text{ m})} = -0.766\ \frac{\text{m}}{\text{s}^2}$$

The force exerted on the swimmer by the water is

$$F = m(-a) = (40.0\text{ kg})\left(0.766\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{30.6\text{ N}}$$

47. **(a)** $a = \frac{F}{m} = \frac{1200\text{ N}}{2.2\times 10^5\text{ kg}} = \boxed{0.0055\text{ m/s}^2}$

(b) $v^2 = v_0^2 + 2a\Delta x$

$$\Delta x = \frac{v^2 - v_0^2}{2a} = \frac{(9500\text{ m/s})^2 - 0}{2(5.45\times 10^{-3}\text{ m/s}^2)} = 8.3\times 10^9\text{ m} = \boxed{8.3\times 10^6\text{ km}}$$

(c) Let d represent the acceleration distance. Then $d = \frac{1}{2}aT^2$, where T is the total time required.

$$T = \sqrt{\frac{2d}{a}}$$

The time to travel one half the distance d is

$$t = \sqrt{\frac{2\left(\frac{1}{2}d\right)}{a}} = \sqrt{\frac{d}{a}} = \frac{1}{\sqrt{2}}T = 0.707T$$

For the first half of the distance the average speed is $\frac{\frac{1}{2}d}{0.707T}$. For the second half of the distance the average speed is $\frac{\frac{1}{2}d}{T - 0.707T} = \frac{\frac{1}{2}d}{0.293T}$.

The ratio of first half average speed to second half average speed is

$$\frac{\frac{\frac{1}{2}d}{0.707T}}{\frac{\frac{1}{2}d}{0.293T}} = \frac{0.293}{0.707} = \boxed{0.414}.$$

48. $\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}} = (5.95\text{ kg})[(1.17\text{ m/s}^2)\hat{\mathbf{x}} + (-0.664\text{ m/s}^2)\hat{\mathbf{y}}]$

$= (6.96\text{ N})\hat{\mathbf{x}} + (-3.95\text{ N})\hat{\mathbf{y}}$

$\vec{\mathbf{F}}_3 = \sum \vec{\mathbf{F}} - (\vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2)$

$= (6.96\text{ N})\hat{\mathbf{x}} + (-3.95\text{ N})\hat{\mathbf{y}} - [(3.22\text{ N})\hat{\mathbf{x}} + (-1.55\text{ N})\hat{\mathbf{x}} + (2.05\text{ N})\hat{\mathbf{y}}]$

$= \boxed{(5.29\text{ N})\hat{\mathbf{x}} + (-6.00\text{ N})\hat{\mathbf{y}}}$

49. Find the acceleration.

$$x = \frac{1}{2}at^2$$

$$a = \frac{2x}{t^2} = \frac{2(2.29\text{ m})}{(3.00\text{ s})^2} = 0.509\ \frac{\text{m}}{\text{s}^2}$$

Find the mass of the dog food.

$$F = (m_{\text{cart}} + m_{\text{food}})a$$

$$m_{\text{food}} = \frac{F}{a} - m_{\text{cart}} = \frac{12.0\text{ N}}{0.509\ \frac{\text{m}}{\text{s}^2}} - 14.5\text{ kg} = \boxed{9.1\text{ kg}}$$

50. (a) $\frac{2300\text{ N}}{(67\text{ kg})(9.81\text{ m/s}^2)} = \boxed{3.5}$

(b) $a_y = \frac{\sum F_y}{m} = \frac{2300\text{ N} + (67\text{ kg})(-9.81\text{ m/s}^2)}{67\text{ kg}} = \boxed{25\text{ m/s}^2}$

(c) $\Delta v_y = a_y t = (25\text{ m/s}^2)(1.0\times10^{-3}\text{ s}) = \boxed{0.025\text{ m/s}}$

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

(b) $\sum F_y = ma_y = (2.0\times10^{-3}\text{ kg})(99\text{ m/s}^2) = 0.198\text{ N}$

$\sum F_y = F_{\text{legs}} - mg$

$F_{\text{legs}} = \sum F_y + mg = 0.198\text{ N} + (0.002\text{ kg})(9.81\text{ m/s}^2) = \boxed{0.22\text{ N}}$

(c) It [stays the same], assuming the required takeoff speed and leg extension remain the same. However, the takeoff [force increases], because the mass increases.

52. $a_{\text{av}} = \dfrac{\Delta v}{\Delta t} = \left(\dfrac{155\ \frac{\text{mi}}{\text{h}} - 0}{2.00\text{ s}}\right)\left(\dfrac{1609\text{ m}}{\text{mi}}\right)\left(\dfrac{1\text{ h}}{3600\text{ s}}\right) = 34.6\ \dfrac{\text{m}}{\text{s}^2}$

$m = \dfrac{F}{a} = \dfrac{5.10\times10^6\text{ N}}{34.6\ \frac{\text{m}}{\text{s}^2}} = \boxed{1.47\times10^5\text{ kg}}$

53. (a) Determine the deceleration of the arrow.

$a = \dfrac{v^2 - v_0{}^2}{2\Delta x} = \dfrac{0 - \left(43\ \frac{\text{m}}{\text{s}}\right)^2}{2(0.050\text{ m–0})} = -18{,}490\ \dfrac{\text{m}}{\text{s}^2}$

Calculate the average force.

$F = ma = (0.010\text{ kg})\left(-18{,}490\ \dfrac{\text{m}}{\text{s}^2}\right) = \boxed{-180\text{ N}}$

(b) The acceleration must be half of its previous value. The penetration depth [doubles].

54. (a) $mg = (0.13\text{ kg})(9.81\text{ m/s}^2) = \boxed{1.3\text{ N}}$

(b) $v^2 = v_0^2 + 2g\Delta y = 0 + 2(9.81\text{ m/s}^2)(3.2\text{ m}) = 62.8\text{ m}^2/\text{s}^2$

$v = \boxed{7.9\text{ m/s}}$

(c) $mgh = (0.13\text{ kg})(9.81\text{ m/s}^2)(3.2\text{ m}) = \boxed{4.1\text{ kg}\cdot\text{m}^2/\text{s}^2}$

$\dfrac{1}{2}mv^2 = \dfrac{1}{2}(0.13\text{ kg})(62.8\text{ m}^2/\text{s}^2) = \boxed{4.1\text{ kg}\cdot\text{m}^2/\text{s}^2}$

Dimensions of both quantities are $\boxed{ML^2/T^2}$.

55. (a) $a = \dfrac{\sum F}{m} = \dfrac{0.22\text{ N}}{0.13\text{ kg}} = \boxed{1.7\text{ m/s}^2}$

(b) $v^2 = v_0^2 + 2a\Delta x = 0 + 2(1.69\text{ m/s}^2)(0.25\text{ m}) = 0.845\text{ m}^2/\text{s}^2$

$v = \boxed{0.92\text{ m/s}}$

(c) $Fd = (0.22\text{ N})(0.25\text{ m}) = \boxed{0.055\text{ N}\cdot\text{m}}$

$$\frac{1}{2}mv^2 = \frac{1}{2}(0.13\text{ kg})(0.845\text{ m}^2/\text{s}^2) = \boxed{0.055\text{ kg}\cdot\text{m}^2/\text{s}^2}$$

$$\text{N}\cdot\text{m} = [(\text{kg})(\text{m/s}^2)]\cdot\text{m} = \text{kg}\cdot\text{m}^2/\text{s}^2$$

Dimensions of both Fd and $\frac{1}{2}mv^2$ are $\boxed{\frac{[\text{M}][\text{L}^2]}{[\text{T}^2]}}$.

56. (a) $a = \frac{\sum F}{m} = \frac{260{,}000\text{ N}}{3800\text{ kg}} = \boxed{68\text{ m/s}^2 = 7.0g}$

(b) $v^2 = v_0^2 + 2g\Delta y = 0 + 2(9.81\text{ m/s}^2)(1.46\text{ m}) = 28.6\text{ m}^2/\text{s}^2$

As it hits the ground its speed is $v = 5.35$ m/s.

$v = v_0 + at$

$0 = -5.35\text{ m/s} + (68\text{ m/s}^2)t,$ taking up to be the positive direction

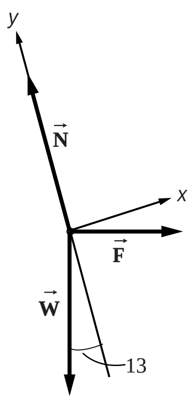
$t = \boxed{0.079\text{ s}}$

57. $a = \frac{\Delta v}{t} = \frac{7900\text{ mi/h} - 0}{16{,}000\text{ h}} = 0.4938\ \frac{\text{mi}}{\text{h}^2}\left(\frac{1609\text{ m}}{\text{mi}}\right)\left(\frac{\text{h}}{3600\text{ s}}\right)^2 = 6.13\times10^{-5}\ \text{m/s}^2$

$$F = (0.064\text{ oz})\left(\frac{\text{lb}}{16\text{ oz}}\right)\left(\frac{4.448\text{ N}}{\text{lb}}\right) = 0.0178\text{ N}$$

$$m = \frac{F}{a} = \frac{0.0178\text{ N}}{6.13\times10^{-5}\ \text{m/s}^2} = \boxed{290\text{ kg}}$$

58. (a)



(b) $\sum F_x = F\cos\theta - mg\sin\theta = 0$

$$F = \frac{mg\sin\theta}{\cos\theta} = mg\tan\theta = (7.5\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\tan 13° = \boxed{17\text{ N}}$$

(c) $\sum F_y = N - mg\cos\theta = 0$

$$N = mg\cos\theta = (7.5\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\cos 13° = \boxed{72\text{ N}}$$

59. Choose the positive x-direction along the path of the ball after it leaves the bat. Find the average acceleration.

$$a = \frac{\Delta v}{\Delta t} = \frac{25\ \frac{\text{m}}{\text{s}} - \left(-43\ \frac{\text{m}}{\text{s}}\right)}{0.0020\ \text{s}} = 34,000\ \frac{\text{m}}{\text{s}^2}$$

Find the average force.

$$F = ma = (0.15\ \text{kg})\left(34,000\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{5.1\ \text{kN}}$$

60. **(a)** If the bag is raised with constant speed, the only acceleration acting on its contents is g.

$$m = \frac{F}{g} = \frac{51.0\ \text{N}}{9.81\ \frac{\text{m}}{\text{s}^2}} = \boxed{5.20\ \text{kg}}$$

(b) $F - mg = ma$

$$m = \frac{F}{g + 1.35\ \frac{\text{m}}{\text{s}^2}} = \frac{51.0\ \text{N}}{9.81\ \frac{\text{m}}{\text{s}^2} + 1.35\ \frac{\text{m}}{\text{s}^2}} = \boxed{4.57\ \text{kg}}$$

61. **(a)** Determine the acceleration during takeoff.

$$x = \frac{1}{2}at^2$$

$$a = \frac{2x}{t^2} = \frac{2(1.0\times 10^3\ \text{m})}{(35\ \text{s})^2} = 1.63\ \frac{\text{m}}{\text{s}^2}$$

Find the force.

$$F = ma = (1.70\times 10^5\ \text{kg})\left(1.63\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{280\ \text{kN}}$$

(b) Determine the acceleration during takeoff using the given data (x, t). Then calculate the force using $F = ma$.

62. **(a)** Find the acceleration.

$$a = \frac{v_\text{f}^2 - v_0^2}{2\Delta y} = \frac{\left(4.1\ \frac{\text{m}}{\text{s}}\right)^2 - 0}{2(3.2\ \text{m}-0)} = 2.63\ \frac{\text{m}}{\text{s}^2}$$

Find the force of the pole on the fireman.

$$F = mg - ma = m(g-a) = (92\ \text{kg})\left(9.81\ \frac{\text{m}}{\text{s}^2} - 2.63\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{660\ \text{N}}$$

(b) No, the landing speed is not doubled.

a is reduced by a factor of 4, and in general $F = mg - \frac{ma}{4} \neq 2m(g-a)$.

(c)
$$a = \frac{\left(2.05\ \frac{\text{m}}{\text{s}}\right)^2}{2(3.2\ \text{m})} = 0.657\ \frac{\text{m}}{\text{s}^2}$$

$$F = m(g-a) = (92\ \text{kg})\left(9.81\ \frac{\text{m}}{\text{s}^2} - 0.657\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{840\ \text{N}}$$

63. $M = 1220$ kg

m = mass of friend

$$\sum F_y = F_{\text{balloon}} + W = -(M+m)a$$

$$Mg - (M+m)g = -(M+m)a$$

$$-mg = -Ma - ma$$

$$m(g-a) = Ma$$

$$m = M\left(\frac{a}{g-a}\right)$$

$$= (1220 \text{ kg})\left(\frac{0.56 \frac{\text{m}}{\text{s}^2}}{9.81 \frac{\text{m}}{\text{s}^2} - 0.56 \frac{\text{m}}{\text{s}^2}}\right)$$

$$= \boxed{74 \text{ kg}}$$

64. Determine the acceleration.

$$a = \frac{v_\text{f}^2 - v_\text{i}^2}{2\Delta x}$$

Calculate the average force.

$$F = ma = m\left(\frac{v_\text{f}^2 - v_\text{i}^2}{2\Delta x}\right) = m\left(\frac{0 - v^2}{2\Delta x}\right) = \boxed{-\frac{mv^2}{2\Delta x}}$$

65. $F_1 + F_2 = ma_1$

$-F_1 + F_2 = ma_2$

Solve for F_2 by adding these equations.

$$2F_2 = ma_1 + ma_2$$

$$F_2 = \frac{m}{2}(a_1 + a_2)$$

Solve for F_1 by substituting the result for F_1 into one of the original equations.

$$F_1 + \frac{m}{2}(a_1 + a_2) = ma_1$$

$$F_1 = ma_1 - \frac{m}{2}a_1 - \frac{m}{2}a_2$$

$$= \frac{m}{2}(a_1 - a_2)$$

$$\boxed{F_1 = \frac{m}{2}(a_1 - a_2)}$$

$$\boxed{F_2 = \frac{m}{2}(a_1 + a_2)}$$

66. (a) Determine the deceleration.

$$-a = \frac{v^2 - v_0^2}{2\Delta x} = \frac{0 - \left(18 \frac{\text{m}}{\text{s}}\right)^2}{2(1.0 \text{ m}–0)} = -162 \frac{\text{m}}{\text{s}^2}$$

$$F = ma = (65 \text{ kg})\left(162 \frac{\text{m}}{\text{s}^2}\right) = \boxed{11 \text{ kN}}$$

(b) $-a = \dfrac{v^2 - v_0{}^2}{2\Delta x} = \dfrac{0-\left(18\ \frac{\text{m}}{\text{s}}\right)^2}{2(0.01\ \text{m}-0)} = -16,200\ \dfrac{\text{m}}{\text{s}^2}$

$F = ma = (65\ \text{kg})\left(16{,}200\ \dfrac{\text{m}}{\text{s}^2}\right) = \boxed{1.1\ \text{MN}}$

67. **(a)** $a_1 = \dfrac{F_1}{m_1} = \dfrac{-1.5\ \text{N}}{0.14\ \text{kg}} = \boxed{-11\ \text{m/s}^2}$

$a_2 = \dfrac{F_2}{m_2} = \dfrac{1.5\ \text{N}}{0.25\ \text{kg}} = \boxed{6.0\ \text{m/s}^2}$

(b) $v_1 = v_0 + a_1 t$ and $v_2 = 0 + a_2 t$

But $v_1 = v_2$, so $v_0 + a_1 t = a_2 t$

$1.3\ \text{m/s} + (-11\ \text{m/s}^2)t = (6.0\ \text{m/s}^2)t$

$t = \boxed{0.076\ \text{s}}$

(c) $v_1 = v_2 = (6.0\ \text{m/s}^2)(0.076\ \text{s}) = \boxed{0.46\ \text{m/s}}$

(d) $m_1 v_0 = (0.14\ \text{kg})(1.3\ \text{m/s}) = \boxed{0.18\ \text{kg}\cdot\text{m/s}}$

$(m_1 + m_2)v_\text{f} = (0.14\ \text{kg} + 0.25\ \text{kg})(0.46\ \text{m/s}) = \boxed{0.18\ \text{kg}\cdot\text{m/s}}$