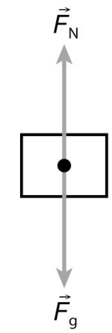
Chapter 3 Review, pages 154–159

Knowledge

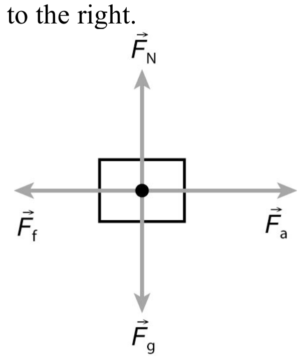
1. (c)
2. (a)
3. (d)
4. (d)
5. (d)
6. (c)
7. (b)
8. (c)
9. False. One newton is equal to 1 kg·m/s^2.
10. False. A *normal* force is a perpendicular force acting on an object that is exerted by the surface with which it is in contact.
11. True
12. True
13. False. To determine the net force, you *do* need to consider the direction of each force acting on an object.
14. False. An object with less mass has *less* inertia. An object with *more* mass has more inertia.
15. True
16. True
17. False. Newton's third law states that for every action force there is a simultaneous reaction force of *equal* magnitude in the opposite direction.
18. (a) (iii)
(b) (v)
(c) (ii)
(d) (i)
(e) (iv)
19. The acceleration due to gravity is 9.8 m/s^2.
20. Answers may vary. Sample answer:
An object that has a lot of inertia has a much stronger resistance to changes in motion. If it is at rest, then it will require more force to start moving it. If it is in motion, then it will require more force to change that motion. Similarly, an object with less inertia has less resistance to changes in motion.
21. Answers may vary. Sample answer:
Newton's third law states that for any force that acts on an object, whether a push or a pull, in contact or at a distance, that object will exert a force of equivalent strength in the opposite direction. For example, if a water bottle sits on a desk, the water bottle exerts a downward force on the desk and the desk exerts an equivalent upward force on the water bottle.

Understanding

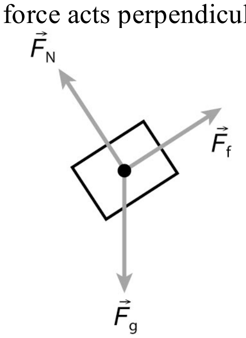
22.



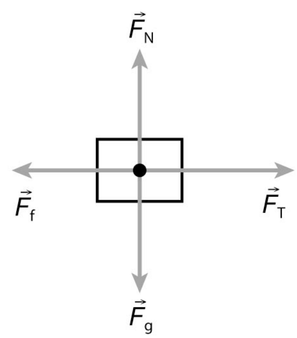
23. The frictional force acting to the left is missing. It is equal in magnitude to the applied force acting to the right.



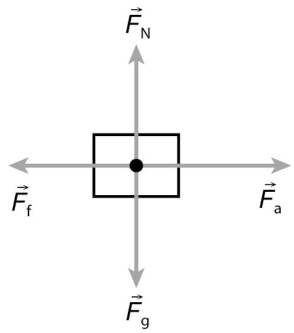
24. The FBD is incomplete. The normal force exerted by the surface of the ramp on the block is missing. This force acts perpendicular to the ramp.



25. (a)



(b)



(c) Answers may vary. Sample answer:
The only difference between the FBDs in parts (a) and (b) is the label for the force the student puts on the box (a push versus a tension force). The direction of each arrow depends on the direction you choose to start drawing a FBD. If you choose right for the direction of the pulling force in (a) and you choose right for the direction of the pushing force in (b), you will end up with the same force diagram for the two different situations.

26. Choose force northward as positive. So, force southward is negative.

Given: $\vec{F}_{\text{northward}} = 37\ 850$ N [northward]; $\vec{F}_{\text{southward}} = 850$ N [southward]

Required: $\vec{F}_{\text{net}}$

Analysis: $\vec{F}_{\text{net}} = \vec{F}_{\text{northward}} + \vec{F}_{\text{southward}}$

Solution:

$$\vec{F}_{\text{net}} = \vec{F}_{\text{northward}} + \vec{F}_{\text{southward}}$$
$$F_{\text{net}} = +37\ 850\ \text{N} + (-850\ \text{N})$$
$$F_{\text{net}} = +37\ 000\ \text{N}$$

Statement: The net horizontal force on the plane is 37 000 N [northward].

27. Choose east as positive. So, west is negative.

Given: $\vec{F}_{\text{downward1}} = 35\ 000$ N [westward]; $\vec{F}_{\text{downward2}} = 1200$ N [westward]

Required: $\vec{F}_{\text{net}}$

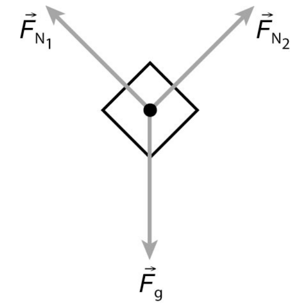
Analysis: $\vec{F}_{\text{net}} = \vec{F}_{\text{downward1}} + \vec{F}_{\text{downward2}}$

Solution:

$$\vec{F}_{\text{net}} = \vec{F}_{\text{downward}} + \vec{F}_{\text{downward}}$$
$$= -35\ 000\ \text{N} + (-1200\ \text{N})$$
$$F_{\text{net}} = -36\ 200\ \text{N}$$
$$\vec{F}_{\text{net}} = 36\ 200\ \text{N [westward]}$$

Statement: The net horizontal force on the plane is 36 200 N [westward].

28.



29. Answers may vary. Sample answer:
Newton's first law implies that since the object is at rest, the net force on the object must be zero. So, the normal force pushing upward on the book must be equal to the force of gravity pulling downward. Otherwise, the book would move either upward or downward.

30. Choose right as positive. So, left is negative. Since the rope is stationary, $\vec{F}_{\text{net}} = 0$.

Given: $\vec{F}_{\text{net}} = 0$; $\vec{F}_{\text{R1}} = 84$ N [right]; $\vec{F}_{\text{R2}} = 86$ N [right]; $\vec{F}_{\text{L1}} = 83$ N [left]

Required: the second child's force of pull, $\vec{F}_{\text{L2}}$

Analysis: $\vec{F}_{\text{net}} = \vec{F}_{\text{R1}} + \vec{F}_{\text{R2}} + \vec{F}_{\text{L1}} + \vec{F}_{\text{L2}}$

$$\vec{F}_{\text{net}} = \vec{F}_{\text{R1}} + \vec{F}_{\text{R2}} + \vec{F}_{\text{L1}} + \vec{F}_{\text{L2}}$$
$$F_{\text{net}} = F_{\text{R1}} + F_{\text{R2}} + F_{\text{L1}} + F_{\text{L2}}$$
$$0 = +84\ \text{N} + 86\ \text{N} + (-83\ \text{N}) + F_{\text{l2}}$$
$$F_{\text{L2}} = -87\ \text{N}$$
$$\vec{F}_{\text{L2}} = 87\ \text{N}$$

Statement: The second child on the left is pulling with a force of 87 N [left].

31. If the box does not move, the net force on the box is zero. So, the magnitude of the frictional force exerted by the ground on the box is 20 N.

32. (a) According to Newton's second law, the acceleration of an object is directly proportional to the net force and inversely proportional to the mass of the object. If the same force acts on two cars with different masses, the car with less mass will have a greater acceleration.

(b) Since the mass of the box is decreasing and the person continues to pull with a constant force, the acceleration of the cart will increase.

33. (a) Given: $m = 69$ kg; $\vec{a} = 2.1\ \text{m/s}^2$ [forward]

Required: $\vec{F}_{\text{net}}$

Analysis: According to Newton's second law,
$\vec{F}_{\text{net}} = m\vec{a}$

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$= (69\text{ kg})(2.1\text{ m/s}^2)\text{ [forward]}$$
$$\vec{F}_{net} = 140\text{ N [forward]}$$

Statement: The net force is 140 N [forward].

(b) Since the basketball is falling due to gravity, $\vec{a} = \vec{g} = 9.8\text{ m/s}^2$ [down].

Given: m = 620 g = 0.62 kg; $\vec{g} = 9.8\text{ m/s}^2$ [down]

Required: $\vec{F}_{net}$

Analysis: According to Newton's second law, $\vec{F}_{net} = m\vec{a} = m\vec{g}$

Solution:

$$\vec{F}_{net} = m\vec{g}$$
$$= (0.62\text{ kg})(9.8\text{ m/s}^2)\text{ [down]}$$
$$\vec{F}_{net} = 6.1\text{ N [down]}$$

Statement: The net force is 6.1 N [down].

34. (a) Given: m = 260 kg; $\vec{F}_{net}$ = 468 N [N]

Required: $\vec{a}$

Analysis: According to Newton's second law, $\vec{F}_{net} = m\vec{a}$

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$= \frac{468\text{ N [N]}}{260\text{ kg}}$$
$$\vec{a} = 1.8\text{ m/s}^2\text{ [N]}$$

Statement: The net acceleration of the boat is 1.8 m/s^2 [N].

(b) Given: m = 70.0 kg; $\vec{F}_{net}$ = 236 N [up]

Required: $\vec{a}$

Analysis: According to Newton's second law, $\vec{F}_{net} = m\vec{a}$

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$= \frac{236\text{ N [up]}}{70.0\text{ kg}}$$
$$\vec{a} = 3.37\text{ m/s}^2\text{ [up]}$$

Statement: The net acceleration of the skydiver is 3.37 m/s^2 [up].

35. Given: m = 10 kg; F_{net} = 40 N

Required: a

Analysis: According to Newton's second law, $F_{net} = ma$

Solution:
The net force on the box acts in the opposite direction of the frictional force.

$$F_{net} = ma$$
$$a = \frac{F_{net}}{m}$$
$$= \frac{40\text{ N}}{10\text{ kg}}$$
$$a = 4\text{ m/s}^2$$

Statement: The box slows down with an acceleration of 4 m/s^2 [opposite direction of motion].

36. Given: m = 175 g = 0.175 kg; a = 1.5 m/s^2

Required: $\vec{F}_f$

Analysis: According to Newton's second law, $\vec{F}_f = m\vec{a}$

Solution:
The frictional force on the puck acts in the opposite direction of the puck's motion.

$$\vec{F}_f = m\vec{a}$$
$$F_f = (0.175\text{ kg})(1.5\text{ m/s}^2)$$
$$F_f = 0.26\text{ N}$$

Statement: The frictional force acting on the puck is 0.26 N [opposite direction of motion].

37. Given: F_{net} = 800 000 N; $\vec{a}$ = 8.0 m/s^2 [forward]

Required: m

Analysis: For the airplane, $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$m = \frac{\vec{F}_{net}}{\vec{a}}$$
$$= \frac{800\ 000\text{ N}}{8\text{ m/s}^2}$$
$$m = 100\ 000\text{ kg}$$

Statement: The mass of the plane is 100 000 kg.

38. Given: $\vec{F}_{net}$ = 1.80 × 10^3 N [S]; m = 145 g = 0.145 kg

Required: $\vec{a}$

Analysis: For the baseball, $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$= \frac{1.80\times10^3\text{ N [S]}}{0.145\text{ kg}}$$
$$\vec{a} = 1.24\times10^4\text{ m/s}^2\text{ [S]}$$

Statement: The acceleration of the ball is 1.24×10^4 m/s^2 [S].

39. (a) Given: m_1 = 2.3 kg; m_2 = 1.7 kg; g = 9.8 m/s^2

Required: $\vec{a}$

Analysis: For the cart, $\vec{F}_{\text{net}} = \vec{F}_{\text{T}}$.

$m_1\vec{a} = \vec{F}_{\text{T}}$ (Equation 1)

For the hanging object, $\vec{F}_{\text{net}} = \vec{F}_{\text{g}} - \vec{F}_{\text{T}}$.

$m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{T}}$ (Equation 2)

Solution: Add the equations to solve for a.

$$m_1\vec{a} + m_2\vec{a} = \vec{F}_{\text{T}} + m_2\vec{g} - \vec{F}_{\text{T}}$$
$$(m_1 + m_2)\vec{a} = m_2\vec{g}$$
$$\vec{a} = \frac{m_2\vec{g}}{m_1 + m_2}$$
$$a = \frac{(1.7\ \cancel{\text{kg}})(9.8\ \text{m/s}^2)}{2.3\ \cancel{\text{kg}} + 1.7\ \cancel{\text{kg}}}$$
$$a = 4.2\ \text{m/s}^2$$

Statement: The acceleration of the cart is 4.2 m/s^2 [right].

(b) Given: m_1 = 2.3 kg; m_2 = 1.7 kg; g = 9.8 m/s^2 ; F_{f} = 0.6 N

Required: $\vec{a}$

Analysis: For the cart, $\vec{F}_{\text{net}} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}}$.

$m_1\vec{a} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}}$ (Equation 1)

For the hanging object, $\vec{F}_{\text{net}} = \vec{F}_{\text{g}} - \vec{F}_{\text{T}}$.

$m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{T}}$ (Equation 2)

Solution: Add the equations to solve for $\vec{a}$.

$$m_1\vec{a} + m_2\vec{a} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}} + m_2\vec{g} - \vec{F}_{\text{T}}$$
$$(m_1 + m_2)\vec{a} = m_2\vec{g} - \vec{F}_{\text{f}}$$
$$\vec{a} = \frac{m_2\vec{g} - \vec{F}_{\text{f}}}{m_1 + m_2}$$
$$a = \frac{(1.7\ \cancel{\text{kg}})(9.8\ \text{m/s}^2) - 0.6\ \text{N}}{2.3\ \cancel{\text{kg}} + 1.7\ \cancel{\text{kg}}}$$
$$a = 4.0\ \text{m/s}^2$$

Statement: The acceleration of the cart is 4.0 m/s^2 [right].

40. (a) Given: m_1 = 1.8 kg; g = 9.8 m/s^2; a = 2.5 m/s^2

Required: m_2, mass of the attached object

Analysis: For the cart, $\vec{F}_{\text{net}} = \vec{F}_{\text{T}}$.

$m_1\vec{a} = \vec{F}_{\text{T}}$ (Equation 1)

For the hanging object, $\vec{F}_{\text{net}} = \vec{F}_{\text{g}} - \vec{F}_{\text{T}}$.

$m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{T}}$ (Equation 2)

Solution: Add the equations to solve for m_2.

$$m_1\vec{a} + m_2\vec{a} = \vec{F}_{\text{T}} + m_2\vec{g} - \vec{F}_{\text{T}}$$
$$m_1\vec{a} + m_2\vec{a} = m_2\vec{g}$$
$$m_1\vec{a} = m_2\vec{g} - m_2\vec{a}$$
$$m_1\vec{a} = m_2(\vec{g} - \vec{a})$$
$$m_2 = \frac{m_1\vec{a}}{\vec{g} - \vec{a}}$$
$$= \frac{(1.8\ \text{kg})(2.5\ \cancel{\text{m/s}^2})}{9.8\ \cancel{\text{m/s}^2} - 2.5\ \cancel{\text{m/s}^2}}$$
$$m_2 = 0.62\ \text{kg}$$

Solution: The mass of the attached object is 0.62 kg.

(b) Given: m_1 = 1.8 kg; g = 9.8 m/s^2; a = 2.5 m/s^2; F_{f} = 0.6 N

Required: m_2, mass of the attached object

Analysis: For the cart, $\vec{F}_{\text{net}} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}}$.

$m_1\vec{a} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}}$ (Equation 1)

For the hanging object, $\vec{F}_{\text{net}} = \vec{F}_{\text{g}} - \vec{F}_{\text{T}}$.

$m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{T}}$ (Equation 2)

Solution: Add the equations to solve for m_2.

$$m_1\vec{a} + m_2\vec{a} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}} + m_2\vec{g} - \vec{F}_{\text{T}}$$
$$m_1\vec{a} + m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{f}}$$
$$m_1\vec{a} + \vec{F}_{\text{f}} = m_2\vec{g} - m_2\vec{a}$$
$$m_1\vec{a} + \vec{F}_{\text{f}} = m_2(\vec{g} - \vec{a})$$
$$m_2 = \frac{m_1\vec{a} + \vec{F}_{\text{f}}}{g - a}$$
$$= \frac{(1.8\ \text{kg})(2.5\ \cancel{\text{m/s}^2}) + 0.4\ \text{N}}{9.8\ \cancel{\text{m/s}^2} - 2.5\ \cancel{\text{m/s}^2}}$$
$$m_2 = 0.67\ \text{kg}$$

Statement: The mass of the attached object is 0.67 kg.

41. (a) The boat exerts a downward force on the water. The water exerts an equal reaction force that pushes upward on the boat.

(b) The dolphin exerts a downward force on the water. The water exerts an equal reaction force that pushes upward on the dolphin.

(c) As the student jumps off the raft to the right, the student's feet exert an action force pushing the raft to the left. The raft exerts a reaction force pushing the student to the right.

42. As a cannon forces a cannon ball out of the cannon, the cannon applies an action force on the cannon ball. According to Newton's third law, the cannon ball will cause a reaction force that pushes the cannon backward.

43. (a) Given: m = 58 kg; F_{net} = 89 N

Required: $\vec{a}$

Analysis: For the student on the skateboard, $\vec{F}_{\text{net}} = m\vec{a}$.

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$
$$a = \frac{89\ \text{N}}{58\ \text{kg}}$$
$$a = 1.5\ \text{m/s}^2$$

Statement: The acceleration of the student is 1.5 m/s^2 away from the wall.

(b) The wall does not seem to move because it is massive and anchored to the ground. Since $\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$, the force that the student pushes on the wall is not strong enough to have any noticeable effect on the motion of the wall.

44. (a) Given: F_{a} = 75 N; F_{f} = 4.0 N

Required: $\vec{a}$

Analysis: For the girl on her skates, $\vec{F}_{\text{net}} = m\vec{a}$.

Solution:

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$\vec{F}_{\text{a}} - \vec{F}_{\text{f}} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{\text{a}} - \vec{F}_{\text{f}}}{m}$$
$$a = \frac{75\ \text{N} - 4.0\ \text{N}}{62\ \text{kg}}$$
$$a = 1.1\ \text{m/s}^2$$

Statement: The acceleration of the girl is 1.1 m/s^2 away from the rail.

(b) The rail does not appear to move because it is anchored to the ground and a part of a large mass. Since $\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$, the force that the girl pushes on the rail is so small compared to the mass of the rail that the acceleration of the rail is not noticeable.

45. (a) The forces on the object are the tension pulling it upward and the gravity pulling it downward. Add all the vertical forces. Choose up as positive. So, down is negative. Since the elevator is stationary, $\vec{F}_{\text{net}} = 0$.

Given: F_{net} = 0 N; m = 3.0 kg, g = –9.8 m/s^2

Required: $\vec{F}_{\text{T}}$

Analysis: $\vec{F}_{\text{net}} = \vec{F}_{\text{T}} + \vec{F}_{\text{g}}$

Solution:

$$\vec{F}_{\text{net}} = \vec{F}_{\text{T}} + \vec{F}_{\text{g}}$$
$$0 = \vec{F}_{\text{T}} + m\vec{g}$$
$$\vec{F}_{\text{T}} = -m\vec{g}$$
$$F_{\text{T}} = -(3.0\ \text{kg})(-9.8\ \text{m/s}^2)$$
$$F_{\text{T}} = +29\ \text{N}$$

Statement: The tension in the string is 29 N.

(b) Choose up as positive. So, down is negative.

Given: m = 3.0 kg; g = –9.8 m/s^2; a = +1.2 m/s^2

Required: $\vec{F}_{\text{T}}$

Analysis: In this situation, $\vec{F}_{\text{net}} = m\vec{a}$.

$$\vec{F}_{\text{net}} = \vec{F}_{\text{T}} + \vec{F}_{\text{g}}$$
$$m\vec{a} = \vec{F}_{\text{T}} + m\vec{g}$$
$$\vec{F}_{\text{T}} = m\vec{a} - m\vec{g}$$
$$F_{\text{T}} = (3.0\ \text{kg})(+1.2\ \text{m/s}^2) - (3.0\ \text{kg})(-9.8\ \text{m/s}^2)$$
$$F_{\text{T}} = +33\ \text{N}$$

Statement: The tension in the string is 33 N.

(c) Choose up as positive. So, down is negative.

Given: m = 3.0 kg; $\vec{g}$ = –9.8 m/s^2; $\vec{a}$ = –1.4 m/s^2

Required: $\vec{F}_{\text{T}}$

Analysis: In this situation, $\vec{F}_{\text{net}} = m\vec{a}$.

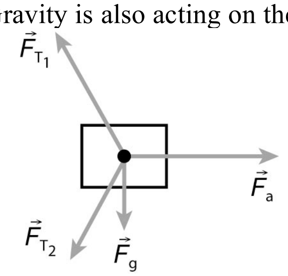
Solution:

$$\vec{F}_{\text{net}} = \vec{F}_{\text{T}} + \vec{F}_{\text{g}}$$
$$m\vec{a} = \vec{F}_{\text{T}} + m\vec{g}$$
$$\vec{F}_{\text{T}} = m\vec{a} - m\vec{g}$$
$$F_{\text{T}} = (3.0\ \text{kg})(-1.4\ \text{m/s}^2) - (3.0\ \text{kg})(-9.8\ \text{m/s}^2)$$
$$F_{\text{T}} = -25\ \text{N}$$

Statement: The tension in the string is 25 N.

Analysis and Application

46. Answers may vary. Sample answer:
The other forces acting on the flag are the forces from the rope or attachments to the pole that hold the flag in place. These forces would be acting westward. Gravity is also acting on the flag.



47. (a) Given: m = 71.5 kg; g = 9.8 m/s^2

Required: $\vec{F}_{\text{net}}$

Analysis: $\vec{F}_{\text{net}} = m\vec{g}$

Solution:

$\vec{F}_{net} = m\vec{g}$

$F_{net} = (71.5 \text{ kg})(9.8 \text{ m/s}^2)$

$F_{net} = 700 \text{ N}$

Statement: The force of gravity acting on the skydiver is 700 N when he jumps.

(b) Given: $m = 71.5$ kg; $g = 9.8$ m/s^2

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{g}$

Solution:

$\vec{F}_{net} = m\vec{g}$

$F_{net} = (71.5 \text{ kg})(9.8 \text{ m/s}^2)$

$F_{net} = 700 \text{ N}$

Statement: The force of gravity acting on the skydiver is 700 N when he lands.

48. Since the girl is not moving, $\vec{F}_{net} = 0$. Add all the vertical forces. Choose up as positive. So, down is negative.

Given: $\vec{F}_{net} = 0$; $m = 45.0$ kg, $g = -9.8$ m/s^2

Required: F_N

Analysis: $\vec{F}_{net} = \vec{F}_N + \vec{F}_g$

Solution:

$\vec{F}_{net} = \vec{F}_N + \vec{F}_g$

$0 = \vec{F}_N + m\vec{g}$

$\vec{F}_N = -m\vec{g}$

$F_N = -(45.0 \text{ kg})(-9.8 \text{ m/s}^2)$

$F_N = +440 \text{ N}$

Statement: The magnitude of the force the bench pushes against the girl is 440 N.

49. The force on a free-falling object is gravity.

Given: $F_{net} = 1100$ N; $g = 9.8$ m/s^2

Required: m

Analysis: $\vec{F}_{net} = m\vec{g}$

Solution:

$\vec{F}_{net} = m\vec{g}$

$m = \dfrac{\vec{F}_{net}}{\vec{g}}$

$m = \dfrac{1100 \text{ N}}{9.8 \text{ m/s}^2}$

$m = 110 \text{ kg}$

Statement: The mass of the boulder is 110 kg.

50. The force on the water is the force of gravity.

Given: $F_{net} = 7.6$ N; $g = 9.8$ m/s^2

Required: m

Analysis: $\vec{F}_{net} = m\vec{g}$

Solution:

$\vec{F}_{net} = m\vec{g}$

$m = \dfrac{\vec{F}_{net}}{\vec{g}}$

$= \dfrac{7.6 \text{ N}}{9.8 \text{ m/s}^2}$

$m = 0.78 \text{ kg}$

Statement: The mass of the water is 0.78 kg.

51. Given: $v = 35$ m/s; $\Delta t = 0.50$ s; $m = 0.25$ kg; $a = 70$ m/s^2

Required: F_{net}

Analysis: $\vec{F}_{net} = m\vec{a}$. First find the acceleration of the T-shirt launcher using $\vec{a} = \dfrac{\Delta\vec{v}}{\Delta\vec{t}}$.

Solution:

$\vec{a} = \dfrac{\Delta\vec{v}}{\Delta\vec{t}}$

$a = \dfrac{35 \text{ m/s}}{0.50 \text{ s}}$

$a = 70 \text{ m/s}^2$

$\vec{F}_{net} = m\vec{a}$

$F_{net} = (0.25 \text{ kg})(70 \text{ m/s}^2)$

$F_{net} = 18 \text{ N}$

Statement: The launcher exerts a force of 18 N on the shirts.

52. Given: $v_i = 6.0$ m/s; $v_f = 15$ m/s; $\Delta t = 3.0$ s

Required: F_{net}

Analysis: $\vec{F}_{net} = m\vec{a}$. First find the acceleration of the runner using $\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t}$.

Solution:

$\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$a = \dfrac{15 \text{ m/s} - 6.0 \text{ m/s}}{3.0 \text{ s}}$

$a = 3.0 \text{ m/s}^2$

$\vec{F}_{net} = m\vec{a}$

$F_{net} = (72 \text{ kg})(3.0 \text{ m/s}^2)$

$F_{net} = 220 \text{ N}$

Statement: The net force acting on the runner is 220 N.

53. (a) Given: $m_1 = 30.0$ kg; $m_2 = 10.0$ kg; $\vec{F}_f = 240$ N [backward]; $\vec{F}_a = 3.0 \times 10^2$ N [forward]

Required: $\vec{a}$
Analysis: $\vec{F}_{net} = \vec{F}_a + \vec{F}_f$. Treat the two boxes as a single object with mass 40.0 kg and a total force of friction of 240 N. Choose forward as positive. So, backward is negative.
Solution:

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$
$$(m_1 + m_2)\vec{a} = \vec{F}_a + \vec{F}_f$$
$$\vec{a} = \frac{\vec{F}_a + \vec{F}_f}{m_1 + m_2}$$
$$a = \frac{+3.0\times 10^2 \text{ N} + (-240 \text{ N})}{30 \text{ kg} + 10 \text{ kg}}$$
$$a = +1.5 \text{ m/s}^2$$
$$\vec{a} = 1.5 \text{ m/s}^2 \text{ [forward]}$$

Statement: The acceleration of the boxes is 1.5 m/s^2 [forward].
(b) If there is no applied force, the only horizontal force acting on the boxes is the force of friction, which acts in the opposite direction of their motion and causes them to slow down.
(c) Given: $\vec{a}_1$ = 1.5 m/s^2 [forward]; Δt = 5.0 s
Required: Δd
Analysis: First calculate the distance when the boxes are accelerating using $\Delta\vec{d}_1 = \frac{1}{2}\vec{a}_1\Delta t^2$. Then calculate the velocity before the boxes slow down using $\vec{v}_i = \vec{a}_1\Delta t$. Then calculate the acceleration of the boxes when the applied force is removed using $\vec{F}_{net} = \vec{F}_f$. Then find the distance travelled when the boxes are slowing down using $\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}_2\Delta\vec{d}_2$. Finally, add the two distances.
Solution:

$$\Delta d_1 = \frac{1}{2}a_1\Delta t^2$$
$$= \frac{1}{2}\left(+1.5\ \frac{\text{m}}{\cancel{\text{s}^2}}\right)(5.0\ \cancel{\text{s}})^{\cancel{2}}$$
$$\Delta d_1 = 18.75 \text{ m (two extra digits carried)}$$

$$\vec{v}_i = \vec{a}_1\Delta t$$
$$v_i = (+1.5 \text{ m/s}^{\cancel{2}})(5.0\ \cancel{\text{s}})$$
$$v_i = +7.5 \text{ m/s}$$

$$\vec{F}_{net} = \vec{F}_f$$
$$(m_1 + m_2)\vec{a}_2 = \vec{F}_f$$
$$\vec{a}_2 = \frac{\vec{F}_f}{m_1 + m_2}$$
$$a_2 = \frac{-240 \text{ N}}{30 \text{ kg} + 10 \text{ kg}}$$
$$a_2 = -6.0 \text{ m/s}^2$$

As the boxes are slowing down:
$\vec{v}_i$ = 7.5 m/s [backward]; a = 6.0 m/s^2 [backward];
v_f = 0 m/s

$$0 = \vec{v}_i^{\,2} + 2\vec{a}_2\Delta d_2$$
$$\vec{v}_i^{\,2} = -2\vec{a}_2\Delta d_2$$
$$\Delta d_2 = \frac{\vec{v}_i^{\,2}}{-2\vec{a}_2}$$
$$= \frac{(-7.5 \text{ m/s})^2}{-2(-6.0 \text{ m/s}^2)}$$
$$\Delta d_2 = 4.6875 \text{ m (three extra digits carried)}$$

$$\Delta d = \Delta d_1 + \Delta d_2$$
$$= 18.75 \text{ m} + 4.6875 \text{ m}$$
$$= 23.4675 \text{ m}$$
$$\Delta d = 23 \text{ m}$$

Statement: The total distance travelled is 23 m.
54. Choose right as positive. So, left is negative.
Given: F_{R1} = +55 N; F_{R2} = +65 N; F_{L1} = –58 N; F_{L2} = –70 N
Required: $\vec{a}$
Analysis: $\vec{F}_{net} = \vec{F}_{R1} + \vec{F}_{R2} + \vec{F}_{L1} + \vec{F}_{L2}$; $\vec{F}_{net} = m\vec{a}$
Solution:

$$\vec{F}_{net} = \vec{F}_{R1} + \vec{F}_{R2} + \vec{F}_{L1} + \vec{F}_{L2}$$
$$F_{net} = +55 \text{ N} + 65 \text{ N} + (-58 \text{ N}) + +(-70 \text{ N})$$
$$F_{net} = -8 \text{ N}$$

The net force on the students is 8 N to the left.

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$a = \frac{-8 \text{ N}}{60 \text{ kg} + 62 \text{ kg} + 59 \text{ kg} + 64 \text{ kg}}$$
$$a = -0.03 \text{ m/s}^2$$

Statement: The students are accelerating 0.03 m/s^2 [left].

55. (a) Given: $F_a = +10$ N; $F_b = +30$ N; $F_c = +25$ N; $F_d = -10$ N; $F_e = -22$ N

Required: $\left(\vec{F}_{\text{net}}\right)_{\text{horizontal}}$; $\left(\vec{F}_{\text{net}}\right)_{\text{vertical}}$

Analysis: $\left(F_{\text{net}}\right)_{\text{horizontal}} = F_b + F_c + F_e$; $\left(F_{\text{net}}\right)_{\text{vertical}} = F_a + F_d$. Choose right and up as positive. So, left and down are negative.

Solution:

$$\begin{aligned}\left(F_{\text{net}}\right)_{\text{horizontal}} &= F_b + F_c + F_e \\ &= +30\text{ N} + 25\text{ N} + (-22\text{ N}) \\ &= +33\text{ N} \\ \left(\vec{F}_{\text{net}}\right)_{\text{horizontal}} &= 33\text{ N [right]}\end{aligned}$$

$$\begin{aligned}\left(F_{\text{net}}\right)_{\text{vertical}} &= F_a + F_d \\ &= +10\text{ N} + (-10\text{ N}) \\ \left(F_{\text{net}}\right)_{\text{vertical}} &= 0\text{ N}\end{aligned}$$

Statement: The net horizontal force is 33 N [right] and the net vertical force is 0 N.

(b) Given: From part (a), $\vec{F}_{\text{net}} = 33$ N [right]; $m = 85$ kg

Required: $\vec{a}$

$$\begin{aligned}\vec{F}_{\text{net}} &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_{\text{net}}}{m} \\ &= \frac{33\text{ N [right]}}{85\text{ kg}} \\ \vec{a} &= 0.39\text{ m/s}^2\text{ [right]}\end{aligned}$$

The acceleration of the box is 0.39 m/s^2 [right].

56. (a) Choose right and up as positive. So, left and down are negative.

Given: $F_a = +13$ N; $F_b = +12$ N; $F_c = +19$ N; $F_d = -26$ N; $F_e = -31$ N

Required: $\left(\vec{F}_{\text{net}}\right)_{\text{horizontal}}$; $\left(\vec{F}_{\text{net}}\right)_{\text{vertical}}$

Analysis: $\left(F_{\text{net}}\right)_{\text{horizontal}} = F_b + F_c + F_e$; $\left(F_{\text{net}}\right)_{\text{vertical}} = F_a + F_d$

Solution:

$$\begin{aligned}\left(F_{\text{net}}\right)_{\text{horizontal}} &= F_b + F_c + F_e \\ &= +12\text{ N} + 19\text{ N} + (-31\text{ N}) \\ \left(F_{\text{net}}\right)_{\text{horizontal}} &= 0\text{ N}\end{aligned}$$

$$\begin{aligned}\left(F_{\text{net}}\right)_{\text{vertical}} &= F_a + F_d \\ &= +13\text{ N} + (-26\text{ N}) \\ &= -13\text{ N} \\ \left(\vec{F}_{\text{net}}\right)_{\text{vertical}} &= 13\text{ N [down]}\end{aligned}$$

Statement: The net horizontal force is 0 N and the net vertical force is 13 N [down].

(b) Given: From part (a), $\vec{F}_{\text{net}} = 13$ N [down]; $\vec{a} = 5.5\text{ m/s}^2$ [down]

Required: m

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$

Solution:

$$\begin{aligned}\vec{F}_{\text{net}} &= m\vec{a} \\ m &= \frac{\vec{F}_{\text{net}}}{\vec{a}} \\ &= \frac{13\text{ N [down]}}{5.5\text{ m/s}^2\text{ [down]}} \\ m &= 2.4\text{ kg}\end{aligned}$$

Statement: The mass of the box is 2.4 kg.

57. (a) Choose right and up as positive. So, left and down are negative.

Given: $m = 12$ kg, $a = 1.5\text{ m/s}^2$; $F_a = +13$ N; $F_b = +82$ N; $F_d = -26$ N; $F_e = -31$ N

Required: F_c

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$; $F_{\text{net}} = F_b + F_c + F_e$

Solution:

$$\begin{aligned}\vec{F}_{\text{net}} &= m\vec{a} \\ &= (12\text{ kg})(1.5\text{ m/s}^2\text{ [right]}) \\ \vec{F}_{\text{net}} &= 18\text{ N [right]}\end{aligned}$$

$$\begin{aligned}F_{\text{net}} &= F_b + F_c + F_e \\ +18\text{ N} &= +82\text{ N} + F_c + (-112\text{ N}) \\ F_c &= +48\text{ N}\end{aligned}$$

The magnitude of F_c is 48 N.

(b) If the box is moving to the left, $\vec{F}_{\text{net}} = 18$ N [left].

Given: $F_{\text{net}} = -18$ N; $F_b = +82$ N; $F_e = -31$ N

Required: F_c

Analysis: $F_{\text{net}} = F_b + F_c + F_e$

Solution:

$$\begin{aligned}F_{\text{net}} &= F_b + F_c + F_e \\ -18\text{ N} &= +82\text{ N} + F_c + (-112\text{ N}) \\ F_c &= +12\text{ N}\end{aligned}$$

Statement: The magnitude of F_c is 12 N.

58. (a) Given: m = 100 kg; Δv = 45 km/h; Δt = 2.5 s
Required: F_{dog}
Analysis: First, convert the velocity to SI units. Then calculate the acceleration using $a = \frac{\Delta v}{\Delta t}$.
Calculate the average applied force using $\vec{F}_{net} = m\vec{a}$. Then determine the average applied force per dog.
Solution:

$$\begin{aligned} \Delta v &= 45 \text{ km/h} \\ &= \left(45 \frac{\cancel{\text{km}}}{\cancel{\text{h}}}\right)\left(\frac{1 \cancel{\text{h}}}{60 \cancel{\text{min}}}\right)\left(\frac{1 \cancel{\text{min}}}{60 \text{ s}}\right)\left(\frac{1000 \text{ m}}{1 \cancel{\text{km}}}\right) \\ \Delta v &= 12.5 \text{ m/s} \end{aligned}$$

$$\begin{aligned} a &= \frac{\Delta v}{\Delta t} \\ &= \frac{12.5 \text{ m/s}}{2.5 \text{ s}} \\ a &= 5.0 \text{ m/s}^2 \end{aligned}$$

$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ F_{net} &= (100 \text{ kg})(5.0 \text{ m/s}^2) \\ F_{net} &= 500 \text{ N} \end{aligned}$$

$$\begin{aligned} F_{dog} &= \frac{500 \text{ N}}{4} \\ F_{dog} &= 125 \text{ N} \end{aligned}$$

Statement: The average force applied by each dog is 125 N.
(b) The frictional force equals the total force applied by the dogs.
Given: F_{dog} = 150 N; F_{net} = 500 N
Required: F_f
Analysis: $F_{net} = F_a - F_f$
Solution:

$$\begin{aligned} F_a &= 4 \times 150 \text{ N} \\ &= 600 \text{ N} \end{aligned}$$

During the pulling motion,

$$\begin{aligned} F_{net} &= F_a - F_f \\ 500 \text{ N} &= 600 \text{ N} - F_f \\ F_f &= 100 \text{ N} \end{aligned}$$

Statement: The frictional force acting on the sled is 100 N [opposite direction of motion]

59. (a) To find the acceleration due to gravity on the Moon, divide the gravitational constant by 6.

$$\frac{9.8 \text{ m/s}^2}{6} = 1.6 \text{ m/s}^2$$

The acceleration due to gravity on the Moon is 1.6 m/s^2.
(b) To find the weight of a person on the Moon, multiply the mass by the unrounded value in part (a).

$$72 \text{ kg} \times \frac{9.8 \text{ m/s}^2}{6} = 120 \text{ N}$$

A 72 kg person would weigh 120 N on the Moon.
(c) The mass of an object on the Moon is its weight divided by the gravitational constant.
The mass of the object is $\frac{700 \text{ N}}{9.8 \text{ m/s}^2}$.
The force on this object on the Moon is its mass multiply by acceleration due to gravity on the Moon. Use the unrounded value in part (a).

$$\frac{700 \text{ N}}{9.8 \text{ m/s}^2} \times \frac{9.8 \text{ m/s}^2}{6} = 120 \text{ N}$$

The force on this object on the Moon is 120 N.
60. (a) As the girl jumps off the raft to the right, the girl's feet exert an action force pushing the raft to the left. The raft exerts a reaction force pushing the girl to the right.
(b) Given: m_g = 55 kg; m_r = 120 kg; F_{net} = 100 N
Required: $\vec{a}_g$; $\vec{a}_r$
Analysis: $\vec{F}_{net} = m\vec{a}$
Solution:
For the girl,

$$\begin{aligned} \vec{F}_{net} &= m_g\vec{a}_g \\ \vec{a}_g &= \frac{\vec{F}_{net}}{m_g} \\ \vec{a}_g &= \frac{100 \text{ N [right]}}{55 \text{ kg}} \\ \vec{a}_g &= 1.8 \text{ m/s}^2 \text{ [right]} \end{aligned}$$

For the raft,

$$\begin{aligned} \vec{F}_{net} &= m_r\vec{a}_r \\ \vec{a}_r &= \frac{\vec{F}_{net}}{m_r} \\ &= \frac{100 \text{ N [left]}}{120 \text{ kg}} \\ \vec{a}_r &= 0.83 \text{ m/s}^2 \text{ [left]} \end{aligned}$$

Statement: The acceleration of the girl is 1.8 m/s^2 [right]. The acceleration of the raft is 0.83 m/s^2 [left].

61. (a) The action force is the force exerted by the boy pushing on the girl. The reaction force is a force of equal magnitude in the opposite direction by the girl pushing back on the boy.
(b) Given: $m_b = 62$ kg; $m_g = 59$ kg; $F_{net} = 74$ N
Required: $\vec{a}_b$; $\vec{a}_g$
Analysis: $\vec{F}_{net} = m\vec{a}$
Solution:
For the boy,

$$\begin{aligned} \vec{a}_b &= \frac{\vec{F}_{net}}{m_b} \\ &= \frac{74 \text{ N [right]}}{62 \text{ kg}} \\ \vec{a}_b &= 1.2 \text{ m/s}^2 \text{ [right]} \end{aligned}$$

For the girl,

$$\begin{aligned} \vec{a}_g &= \frac{\vec{F}_{net}}{m_g} \\ &= \frac{74 \text{ N [left]}}{59 \text{ kg}} \\ \vec{a}_g &= 1.3 \text{ m/s}^2 \text{ [left]} \end{aligned}$$

Statement: The acceleration of the boy is 1.2 m/s^2 [right]. The acceleration of the girl is 1.3 m/s^2 [left].
62. (a) The force on each skater is of equal magnitude. Since $F_{net} = ma$ and skater B has a slower acceleration, skater B has more mass.
(b) The action force is the force of skater A pushing on skater B. The reaction force is the force of skater B pushing back on skater A. The magnitudes of both forces are equal.
Given: $m = 75$ kg; $a = 1.2 \text{ m/s}^2$
Required: F_{net}
Analysis: $\vec{F}_{net} = m\vec{a}$
Solution:

$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ F_{net} &= (75 \text{ kg})(1.2 \text{ m/s}^2) \\ F_{net} &= 90 \text{ N} \end{aligned}$$

Statement: The magnitude of the force is 90 N.
(c)

$$\begin{aligned} F_{net} &= ma \\ m &= \frac{F_{net}}{a} \\ &= \frac{90 \text{ N}}{0.8 \text{ m/s}^2} \\ m &= 110 \text{ kg} \end{aligned}$$

The mass of skater B is 110 kg.

63. (a) Given: $m_{\text{student A}} = 58$ kg; $F_{net} = 80.0$ N
Required: a
Analysis: $\vec{F}_{net} = m_{\text{student A}}\vec{a}$
Solution:

$$\begin{aligned} \vec{F}_{net} &= m_{\text{student A}}\vec{a} \\ \vec{a} &= \frac{\vec{F}_{net}}{m_{\text{student A}}} \\ a &= \frac{80.0 \text{ N}}{58 \text{ kg}} \\ a &= 1.4 \text{ m/s}^2 \end{aligned}$$

Statement: The acceleration of student A is 1.4 m/s^2.
(b) If student B accelerates faster than student A, the total mass on student B's skateboard would be less than 58 kg. So, the mass of the block would be between 0 kg and 3 kg. Similarly, if student B accelerates slower than student A, the total mass on student B's skateboard would be greater than 58 kg. So, the mass of the block would be greater than 3 kg.
(c) Student B and the block accelerate as one single object, so their mass is m.
Given: $a = 1.25 \text{ m/s}^2$; $F_{net} = 80.0$ N; $m_{\text{student B}} = 55$ kg
Required: m_{block}
Analysis: $\vec{F}_{net} = m\vec{a}$
Solution:

$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ m &= \frac{\vec{F}_{net}}{\vec{a}} \\ &= \frac{80.0 \text{ N}}{1.25 \text{ m/s}^2} \\ m &= 64 \text{ kg} \end{aligned}$$

$$\begin{aligned} m_{\text{block}} &= m - m_{\text{student B}} \\ &= 64 \text{ kg} - 55 \text{ kg} \\ m_{\text{block}} &= 9 \text{ kg} \end{aligned}$$

Statement: The mass of the block is 9 kg.
64. (a) Choose right as positive. So, left is negative.
Given: $m_1 = 82$ kg; $m_2 = 64$ kg; $\vec{F}_{net} = 16$ N [left]
Required: $\vec{a}$
Analysis: $\vec{F}_{net} = m\vec{a}$

Solution:
For the male astronaut,

$$\vec{F}_{\text{net}} = m_1\vec{a}_1$$
$$\vec{a}_1 = \frac{\vec{F}_{\text{net}}}{m_1}$$
$$a_1 = \frac{-16\text{ N}}{82\text{ kg}} = -0.20\text{ m/s}^2$$
$$\vec{a}_1 = 0.20\text{ m/s}^2\text{ [left]}$$

For the female astronaut,

$$\vec{F}_{\text{net}} = m_2\vec{a}_2$$
$$\vec{a}_2 = \frac{\vec{F}_{\text{net}}}{m_2}$$
$$a_2 = \frac{+16\text{ N}}{64\text{ kg}} = +0.25\text{ m/s}^2$$
$$\vec{a}_2 = 0.25\text{ m/s}^2\text{ [right]}$$

Statement: The acceleration of the male astronaut is 0.20 m/s^2 [left]. The acceleration of the female astronaut is 0.25 m/s^2 [right].

(b) The answers to part (a) will not change if the male astronaut pushes on the female astronaut instead. In this situation, the action force on the female astronaut becomes the reaction force and the reaction force on the male astronaut becomes the action force.

65. (a) Given: $m_1 = 6.4 \times 10^5$ kg; $m_2 = 5.3 \times 10^5$ kg; $a = 0.12$ m/s^2

Required: F_{net}

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$

Solution:
total mass of the train, $m = m_1 + m_2$

$m = m_1 + m_2$
$= 6.4 \times 10^5\text{ kg} + 5.3 \times 10^5\text{ kg}$
$m = 1.17 \times 10^6$ kg (one extra digit carried)

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$F_{\text{net}} = (1.17\times10^6\text{ kg})(0.12\text{ m/s}^2)$$
$$F_{\text{net}} = 1.4\times10^5\text{ N}$$

Statement: The net force on the entire train is 1.4×10^5 N.

(b) The magnitude of the tension between the locomotive and the train car equals the magnitude of the net force on the train car.

Given: $a = 0.12$ m/s^2; $m = 5.3 \times 10^5$ kg

Required: F_{net}

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$

Solution:

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$F_{\text{net}} = (5.3\times10^5\text{ kg})(0.12\text{ m/s}^2)$$
$$F_{\text{net}} = 6.4\times10^4\text{ N}$$

Statement: The magnitude of the tension between the locomotive and the train car is 6.4×10^4 N.

66. (a) Given: $m_1 = 18$ kg; $m_2 = 12$ kg; $g = 9.8$ m/s^2

Required: F_{TA}; F_{TB}

Analysis: $\vec{F}_{\text{TA}} = (m_1 + m_2)\vec{g}$; $\vec{F}_{\text{TB}} = m_2\vec{g}$

Solution:
For string A,

$$\vec{F}_{\text{TA}} = (m_1 + m_2)\vec{g}$$
$$F_{\text{TA}} = (18\text{ kg} + 12\text{ kg})(9.8\text{ m/s}^2)$$
$$F_{\text{TA}} = 290\text{ N}$$

For string B,

$$\vec{F}_{\text{TB}} = m_2\vec{g}$$
$$F_{\text{TB}} = (12\text{ kg})(9.8\text{ m/s}^2)$$
$$F_{\text{TB}} = 120\text{ N}$$

Statement: The tension in string A is 290 N. The tension in string B is 120 N.

(b) Given: $m_1 = 18$ kg; $m_2 = 12$ kg; $g = 9.8$ m/s^2; $F_{\text{pull}} = 45$ N

Required: F_{TA}; F_{TB}

Analysis: $\vec{F}_{\text{TA}} = (m_1 + m_2)\vec{g} + \vec{F}_{\text{pull}}$; $\vec{F}_{\text{TB}} = m_2\vec{g}$

Solution:
For string A,

$$\vec{F}_{\text{TA}} = (m_1 + m_2)\vec{g} + \vec{F}_{\text{pull}}$$
$$F_{\text{TA}} = (18\text{ kg} + 12\text{ kg})(9.8\text{ m/s}^2) + 45\text{ N}$$
$$F_{\text{TA}} = 340\text{ N}$$

For string B,

$$\vec{F}_{\text{TB}} = m_2\vec{g}$$
$$F_{\text{TB}} = (12\text{ kg})(9.8\text{ m/s}^2)$$
$$F_{\text{TB}} = 120\text{ N}$$

Statement: The tension in string A is 340 N. The tension in string B is 120 N.

(c) Given: $m_1 = 18$ kg; $m_2 = 12$ kg; $g = 9.8$ m/s^2; $F_{\text{pull}} = 45$ N

Required: F_{TA}; F_{TB}

Analysis: $\vec{F}_{\text{TA}} = (m_1 + m_2)\vec{g} + \vec{F}_{\text{pull}}$; $\vec{F}_{\text{TB}} = m_2\vec{g}$

Solution:
For string A,

$$\vec{F}_{TA} = (m_1 + m_2)\vec{g} + \vec{F}_{pull}$$
$$F_{TA} = (18\text{ kg} + 12\text{ kg})(9.8\text{ m/s}^2) + 45\text{ N}$$
$$F_{TA} = 340\text{ N}$$

For string B,

$$\vec{F}_{TB} = m_2\vec{g} + \vec{F}_{pull}$$
$$F_{TB} = (12\text{ kg})(9.8\text{ m/s}^2) + 45\text{ N}$$
$$F_{TB} = 160\text{ N}$$

Statement: The tension in string A is 340 N. The tension in string B is 160 N.
(d) In part (b), the pull on m_1 does not affect the tension in string B, so the tension in string B stays as 120 N. In part (c), the pull on m_2 affects both strings. So, the tension in string B also increases.
(e) If you keep increasing the downward force on m_2, string A will likely break first because the tension in string A is always greater than the tension in string B.
67. Choose right as positive. So, left is negative. Consider the forces on block m_1.
Given: $m_1 = 4.0$ kg; $m_2 = 2.3$ kg; $a = +1.1$ m/s^2; $F_{pull} = 45$ N
Required: F_{TA}; F_{TB}
Analysis: $\vec{F}_{TA} = \vec{F}_{net}$; $\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$;
$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$
Solution:
Consider the forces on block m_1.

$$\vec{F}_{net} = \vec{F}_{TA}$$
$$\vec{F}_{TA} = m_1\vec{a}$$
$$F_{TA} = (4.0\text{ kg})(+1.1\text{ m/s}^2)$$
$$F_{TA} = +4.4\text{ N}$$

Consider the forces on block m_2.

$$\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$$
$$m_2a = -4.4\text{ N} + F_{TB}$$
$$F_{TB} = m_2a + 4.4\text{ N}$$
$$= (2.3\text{ kg})(+1.1\text{ m/s}^2) + 4.4\text{ N}$$
$$F_{TB} = +6.93\text{ N (one extra digit carried)}$$

Consider the forces on block m_3.

$$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$$
$$m_3a = -6.93\text{ N} + F_{TC}$$
$$F_{TC} = m_3a + 6.93\text{ N}$$
$$F_{TC} = (3.4\text{ kg})(+1.1\text{ m/s}^2) + 6.93\text{ N}$$
$$= +10.67\text{ N}$$
$$F_{TC} = +11\text{ N}$$

Statement: The tension in string A is 4.4 N. The tension in string B is 6.9 N. The tension in string C is 11 N.
68. Choose right as positive. So, left is negative.
Given: $m_1 = 4.3$ kg; $m_2 = 5.5$ kg; $m_3 = 3.1$ kg; $a = +1.1$ m/s^2; $F_{net} = +15$ N
Required: $\vec{a}$; F_{TA}; F_{TB}; F_{TC}
Analysis: $\vec{F}_{TA} = \vec{F}_{net}$; $\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$;
$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$
Solution:
Consider the net force acting on the blocks.

$$\vec{F}_{net} = (m_1 + m_2 + m_3)\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m_1 + m_2 + m_3}$$
$$a = \frac{+15\text{ N}}{4.3\text{ kg} + 5.5\text{ kg} + 3.1\text{ kg}}$$
$$= \frac{+15\text{ N}}{12.9\text{ kg}}$$
$$= +1.16\text{ m/s}^2\text{ (one extra digit carried)}$$
$$a = +1.2\text{ m/s}^2$$

Consider the forces on block m_1.

$$\vec{F}_{net} = \vec{F}_{TA}$$
$$\vec{F}_{TA} = m_1\vec{a}$$
$$= (4.3\text{ kg})(+1.16\text{ m/s}^2)$$
$$= +4.99\text{ N (one extra digit carried)}$$
$$F_{TA} = +5.0\text{ N}$$

Consider the forces on block m_2.

$$\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$$
$$m_2a = -4.99\text{ N} + F_{TB}$$
$$F_{TB} = m_2a + 4.99\text{ N}$$
$$= (5.5\text{ kg})(+1.16\text{ m/s}^2) + 4.99\text{ N}$$
$$= +11.4\text{ N (one extra digit carried)}$$
$$F_{TB} = +11\text{ N}$$

Consider the forces on block m_3.

$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$

$m_3 a = -11.4 \text{ N} + F_{TC}$

$F_{TC} = m_3 a + 11.4 \text{ N}$

$\quad = (3.1 \text{ kg})(+1.16 \text{ m/s}^2) + 11.4 \text{ N}$

$F_{TC} = +15 \text{ N}$

Statement: The acceleration of the blocks is 1.2 m/s^2 [right]. The tension in string A is 5.0 N. The tension in string B is 11 N. The tension in string C is 15 N.

69. Choose right as positive. So, left is negative.

Given: $m_1 = 10$ kg; $m_3 = 8$ kg; $F_{net} = +24$ N

Required: m_2; F_{TA}; F_{TB}; F_{TC}

Analysis: $\vec{F}_{TA} = \vec{F}_{net}$; $\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$;

$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$

Solution:

For block m_1,

$\vec{F}_{net} = \vec{F}_{TA}$

$m_1 \vec{a} = \vec{F}_{TA}$

For block m_2, $F_{TB} = 2F_{TA}$, F_{TA} acts to the left.

$\vec{F}_{net} = -\vec{F}_{TA} + \vec{F}_{TB}$

$m_2 \vec{a} = -\vec{F}_{TA} + 2\vec{F}_{TA}$

$m_2 \vec{a} = \vec{F}_{TA}$

So, $m_1 = m_2 = 10$ kg.

Consider the net force acting on the blocks.

$\vec{F}_{net} = (m_1 + m_2 + m_3)\vec{a}$

$$\vec{a} = \frac{\vec{F}_{net}}{m_1 + m_2 + m_3}$$

$$a = \frac{+24 \text{ N}}{10 \text{ kg} + 10 \text{ kg} + 8 \text{ kg}}$$

$$= \frac{+24 \text{ N}}{28 \text{ kg}}$$

$a = +0.86 \text{ m/s}^2$ (one extra digit carried)

For string A,

$\vec{F}_{TA} = m_1 \vec{a}$

$F_{TA} = (10 \text{ kg})(0.86 \text{ m/s}^2)$

$\quad = 8.6 \text{ N}$

$F_{TA} = 9 \text{ N}$

For string B,

$\vec{F}_{TB} = 2\vec{F}_{TA}$

$\quad = 2(8.6 \text{ N})$

$\quad = 17$ N (one extra digit carried)

$F_{TB} = 20 \text{ N}$

For string C,

$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$

$m_3 a = -17 \text{ N} + F_{TC}$

$F_{TC} = m_3 a + 17 \text{ N}$

$\quad = (8 \text{ kg})(+0.86 \text{ m/s}^2) + 17 \text{ N}$

$\quad = 23.9 \text{ N}$

$F_{TC} = 24 \text{ N}$

Statement: The mass of the second block is 10 kg. The tension in string A is 9 N. The tension in string B is 20 N. The tension in string C is 24 N.

70. (a) Choose forward as positive. So, backward is negative. Since the sleds are tied together, treat them as one single object. Consider forces acting on this object to find the total frictional force.

Given: $m_1 = 60.0$ kg; $m_2 = 55.0$ kg; $a = +1.02 \text{ m/s}^2$; $F_a = +230$ N; $F_{front} = 58.8$ N

Required: F_f

Analysis: $\vec{F}_{net} = \vec{F}_a + \vec{F}_f$

Solution:

$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$

$(m_1 + m_2)a = +230 \text{ N} + F_f$

$F_f = (m_1 + m_2)a - 230 \text{ N}$

$\quad = (60.0 \text{ kg} + 55.0 \text{ kg})(+1.02 \text{ m/s}^2) - 230 \text{ N}$

$F_f = -112.7$ N (two extra digits carried)

The force of friction for the back sled is now the positive direction.

$F_{back} = F_f - F_{front}$

$\quad = 112.7 \text{ N} - 58.8 \text{ N}$

$\quad = 53.9$ N (one extra digit carried)

$F_{back} = 54 \text{ N}$

Statement: The frictional force on the back sled is 54 N.

(b) Given: $m_1 = 60.0$ kg; $F_a = +230$ N; $a = +1.02 \text{ m/s}^2$; $F_a = +230$ N; $F_f = -58$ N

Required: F_T

Analysis: $\vec{F}_{net} = \vec{F}_a + \vec{F}_T + \vec{F}_f$

Solution:
Consider forces acting on the front sled,

$$\vec{F}_{\text{net}} = \vec{F}_{\text{a}} + \vec{F}_{\text{T}} + \vec{F}_{\text{f}}$$
$$m_1 a = +230 \text{ N} + F_{\text{T}} + (-58.8 \text{ N})$$
$$F_{\text{T}} = m_1 a - 230 \text{ N} + 58.8 \text{ N}$$
$$= (60.0 \text{ kg})(+1.02 \text{ m/s}^2) - 230 \text{ N} + 58.8 \text{ N}$$
$$F_{\text{T}} = -110 \text{ N}$$

Statement: The tension in the rope connecting the sleds is 110 N.

(c) Given: $m_1 = 60.0$ kg; $m_2 = 55.0$ kg; $a = +1.02$ m/s^2; $\Delta t = 3.0$ s; $F_{\text{f}} = -112.7$ N

Required: F_{T}

Analysis: $\Delta d_1 = \frac{1}{2}\vec{a}\Delta t^2$; $\vec{v} = \vec{a}\Delta t$; $\vec{F}_{\text{net}} = \vec{F}_{\text{f}}$

Solution:
Calculate the distance when the sleds are accelerating.

$$\Delta d_1 = \frac{1}{2}\vec{a}\Delta t^2$$
$$= \frac{1}{2}(1.02 \text{ m/s}^2)(3.0 \text{ s})^2$$
$$\Delta d_1 = 4.59 \text{ m (one extra digit carried)}$$

Calculate the velocity before the sleds slow down.

$$\vec{v} = \vec{a}\Delta t$$
$$v = \left(1.02 \ \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)(3.0 \ \cancel{\text{s}})$$
$$v = 3.06 \text{ m/s}$$

Calculate the acceleration a_1 of the sleds when the applied force is removed.

$$\vec{F}_{\text{net}} = \vec{F}_{\text{f}}$$
$$(m_1 + m_2)\vec{a}_1 = \vec{F}_{\text{f}}$$
$$\vec{a}_1 = \frac{\vec{F}_{\text{f}}}{m_1 + m_2}$$
$$a = \frac{-112.7 \text{ N}}{60.0 \text{ kg} + 55.0 \text{ kg}}$$
$$a = -0.98 \text{ m/s}^2$$

Use the equation $\vec{v}_{\text{f}}^{\,2} = \vec{v}_{\text{i}}^{\,2} + 2\vec{a}\Delta d$ to find the distance travelled when the sleds slow down, given $v_{\text{i}} = -3.06$ m/s; $a = -0.98$ m/s^2; $v_{\text{f}} = 0$ m/s.

$$0 = \vec{v}^2 + 2\vec{a}\Delta d_2$$
$$\vec{v}^2 = -2\vec{a}\Delta d_2$$
$$\Delta d_2 = \frac{\vec{v}^2}{-2\vec{a}}$$
$$= \frac{(-3.06 \text{ m/s})^2}{-2(-9.8 \text{ m/s}^2)}$$
$$\Delta d_2 = 4.777 \text{ m (one extra digit carried)}$$

$$\Delta d = \Delta d_1 + \Delta d_2$$
$$= 4.59 \text{ m} + 4.777 \text{ m}$$
$$= 9.367 \text{ m (one extra digit carried)}$$
$$\Delta d = 9.37 \text{ m}$$

Statement: The total distance travelled is 9.37 m.

Evaluation

71. Answers may vary. Sample answer:
The mass of the Sun is about 1000 times the combined mass of all the planets, which means it has much more inertia. Even if all the planets were aligned and did not have any forces in opposite directions due to their positions, this would still have very little effect on the position of the Sun.

72. (a) Yes, objects on Earth are attracted by the Moon. For example, the gravitational attraction between the Moon and Earth causes the tides.
(b) Nothing on Earth flies off to the Moon because the force of gravity from Earth is much greater than the pull from the Moon.

73. (a) If an action force and a reaction force act on the same object, the net force will be zero and nothing will accelerate. When the fan blows to the right, there is a force on the cart in one direction and there is a force on the cart in the opposite direction resulting from the air hitting the sail. According to Newton's third law, the active fan will cause a reaction force of the same magnitude on the sail but in the opposite direction. The action and reaction forces act on the same object, the sail. As a result the cart will not accelerate.
(b) If the sail is removed, as the fan blows to the right, it pushes the air to the right. According to Newton's third law, there is a reaction force on the air by the fan. The blowing air exerts an equal force but opposite in direction to the blowing fan. The fan cart can then accelerate because there is an external force that pushes it in the opposite direction or to the left.

74. (a) It is possible for the two blocks to remain in place if there is frictional force in the pulleys that could stop the motion.
(b) Since the blocks are stationary, the frictional

force in the pulleys must be greater than or equal to the difference of the weights. If the friction were greater than the difference in weights and one of the blocks were tapped downward, the motion would slow down and stop. If the friction were exactly equal to the difference in weights, the tapped block would keep moving downward.

Reflect on Your Learning

75. Answers may vary. Sample answer:
The statement is not valid when the action and reaction forces are not acting on the same object. If they act on the same object, the net force will be zero and nothing will accelerate. For example, when a ballistic cart pushes backward on a ball, the ball accelerates backward. According to Newton's third law, the ball will cause a reaction force of the same magnitude on the cart in the opposite direction, making the cart accelerate forward. The action and reaction forces do not cancel because they do not act on the same object.

Research

76. Answers may vary. Sample answer:
Students' reports should describe the characteristics of the strong force and how close protons need to be for this interaction to occur. Reports should give estimates, if possible, of the relative strength of this force compared to the electromagnetic force and gravity. There should also be a discussion on how in heavier elements the number of protons is so large that the electromagnetic repulsion is stronger than the strong force, which leads to nuclear fission.

77. Answers may vary. Sample answer:
Students' presentations should mention the experiments and theories of 16th- and early 17th-century scientists, such as Galileo's falling bodies experiment, Kepler's planetary motion theories, and Déscartes' coordinate system. Presentations could include how these views conflicted with popular beliefs of the time.