Section 2.6: Physics Journal: The Physics of Downhill Skiing
Section 2.6 Questions, page 94

1. Answers may vary. Sample answers: Four forces that act on a downhill skier are the force of gravity, the normal force of the ski slope, friction, and air resistance.

2. Answers may vary. Sample answers: The equipment used by downhill skiers reduces friction and resistance in several ways. Applying wax to the bottoms of the skis helps reduce kinetic friction between the skis and the snow, which directly increases the skier's acceleration. Skiers can also use their poles to get a boost of extra force when starting from rest. The perpendicular force reduces the normal force of the slope on the skier, and this reduces kinetic friction.

3. Answers may vary. Sample answers: A large mass does not necessarily cause a skier to go faster. The increased mass of a skier may make it more difficult for the skier to turn effectively.

4. Answers may vary. Sample answers: A helmet is important for a downhill skier because during a crash, a skier's speed changes from a high speed to zero almost immediately. According to Newton's second law of motion, this large change causes a large force to act on the skier. A helmet provides cushioning, which allows the skier's head more time to slow down during a crash and reduces the force on the skier's head.

5. (a) Answers may vary. Sample answer: A ski consists of three main parts, the front or tip of the ski, the middle or waist, and the rear or tail. The top of the ski is usually made of plastic and the base covered in a hard plastic. The base has sharp metal edges on both sides, which are designed to dig into snow or ice. The side-cut of a ski is the shape of the edges as viewed from the top or bottom.

Prior to the 1990s, most downhill skis were long, straight, and with little side-cut. The length from floor to the fingertips of a person's vertically stretched arm was used to determine the length of a person's skis. Later, skis were redesigned to be shorter and parabolic-shaped with a deeper side-cut. The shorter length allows skiers to make turns more easily by reducing the radius of the turn. The deeper side-cut catches or digs into the snow, making it easier to make a turn. Today, a person's skis are usually measured from the floor to the middle of the person's chest. Adding flexibility to ski materials also increased the ability of the skier to glide over or dig into snow. Another improvement includes raising the tip and tail of the ski or adding a rocker. The rocker helps the ski to deflect cut-up snow and to move the ski into its arc sooner. Poles and the increased flexibility of the material help to absorb shock and to protect the skier from injury. Another improvement in technology is the use of quick-release bindings so that, in case of a mishap, skis can be released, slowing down the skier and preventing leg injury if the skis get caught in the snow. These technological changes allow for greater skiing control, especially when making turns, and improved safety.

(b) Answers may vary. Sample answer: Since the 1960s, the number of broken legs in ski accidents has declined by 50 % due to quick-release bindings. Shorter skis have also reduced knee injury rates by reducing the force that the ski tail exerts on a skier's knee. Head injuries have also declined by 50 % through the increased use of helmets. Therefore, improvements in ski equipment have reduced the rate of injury.

(c) Answers may vary. Sample answer: Skiers wear special clothing such as ski suits made of anti-drag fabric to minimize the drag force on their bodies, thus allowing for maximum speed.

Chapter 2 Investigations

Investigation 2.3.1: Observational Study: Static Equilibrium of Forces, page 95

Analyze and Evaluate

(a) The condition for static equilibrium is that the sum of all the forces is equal to zero. The sum of the vertical components of all the forces is zero and the sum of all the horizontal components of all the forces is zero.

(b) Friction between the strings and the pulleys affects the tension in the strings and thereby affects the results of the calculations. The tension in the strings will increase.

(c) Some ways to improve the accuracy of measurements in this investigation are: using very smooth strings and pulleys to reduce friction to a minimum; checking carefully that the circular protractor is properly aligned horizontally; reducing the chance of parallax error when lining up the origin of the protractor with the common point of the three strings.

Apply and Extend

(d) (i) When using a force sensor to replace m_2 in Figure 1(a) with the sensor, the reading increases as angles *b* and *c* decrease.

(ii) This trend implies that the amount of force required to keep the two masses in equilibrium varies with the angles, and thus can be manipulated by the angles. This means that there would be some advantage to keeping the angles small.

(e) Answers may vary. Sample answer: If I pulled down slightly on m_2 so that the point where the strings tie together moves, and then let go, I predict that the masses will move up then back down, very quickly. When I pulled m_2 slightly, m_1 and m_3 moved closer to the pulleys, then sprang back to their equilibrium positions. I predicted that the masses would oscillate around their equilibrium positions, which they did.

Investigation 2.4.1: Controlled Experiment: Inclined Plane and Friction, page 96

Analyze and Evaluate

(a) I manipulated the type of material, and measured and recorded the angles and the coefficients of friction. The type of relationship being tested was a causal relationship.

(b) The coefficients of friction were different for the different objects measured due to variations in the smoothness of the two surfaces in contact with each other, and in the types of material in the objects.

(c) I measured the static and kinetic friction for a wood block, wood block with rubber on base, and brick moving on an inclined plane. The coefficients of static friction were 0.42, 1.30, and 0.34, respectively. The coefficients of kinetic friction were 0.43, 1.32, and 0.36, respectively. Comparing the coefficients of static and kinetic friction for wood, wood with rubber, and brick, the coefficients for the wood with rubber were the greatest.

(d) To improve the accuracy of measurements in this activity, you could repeat the experiment several times to verify the readings, and keep the metre stick completely vertical when taking readings.

Apply and Extend

(e) Answers may vary. Sample answer: One possible way to show that the coefficient of friction for two materials is independent of the mass is to use the same object each time, but increase the normal force by placing different amounts of mass on top of the object.

(f) Answers may vary. Sample answer: Another experimental procedure that can determine the coefficient of kinetic friction using an inclined plane is to use larger angles that allow the object to accelerate down the incline. Use the angle to determine the normal force, use the acceleration to determine friction, and then calculate the coefficient of friction. This method might require the use of a motion sensor.

Investigation 2.4.2: Observational Study: Motion and Pulleys, page 97

Analyze and Evaluate

(a) I expect the values to be quite close. Operator error, lack of precision of measuring instruments and smoothness of the string may account for differences between the two sets of values.
(b) Percent error will vary according to the number of errors that occur during individual student investigations.
(c) Some ways to improve the accuracy of my measurements include repeating the experiment several times to verify the readings, keeping the metre stick vertical when taking readings, carefully setting the protractor, and using string that creates less friction.

Apply and Extend

Answers may vary. Sample answers:
(d) Some other values that could be measured using a similar setup are the acceleration due to gravity, or the friction of the pulley.
(e) Some common mistakes that students and researchers make when designing experiments are not controlling variables accurately and reliably, and not performing enough trials. The results may not be consistent from one trial to another if the variables are not properly controlled, and the results might not be accurate if not enough trials are done.

Chapter 2: Dynamics
Chapter 2 Open
Mini Investigation: Describing Motion Using Newton's Laws, page 61
A. When the cart hits the wall, the mass continues to move toward the wall.
B. Newton's first law of motion describes what happens to the motion of the mass. There is no net force acting on the mass, so it continues to move at reasonably constant velocity.
C. The speed of the cart increases as the mass pulls it.
D. The more masses there are attached to the string, the greater the acceleration of the cart.
E. Newton's second law of motion describes the motion of the cart when pulled by the mass. The masses cause tension in the string, which produces a net force on the cart. The acceleration of the cart depends on the magnitude of the net force.
F. When the spring expands, each cart exerts a force on the other.
G. Newton's third law of motion describes this motion. The spring acts on both of the carts making an action–reaction pair of forces. The first cart pushes the second cart in one direction; the second cart pushes the first cart in the opposite direction.

Chapter 2 Review, pages 100–105

Knowledge

1. (b)
2. (a)
3. (c)
4. (a)
5. (d)
6. (a)
7. (d)
8. (c)
9. (b)
10. False. If only three force of equal magnitude act on an object, the object *may or may not* have a non-zero net force.
11. False. When a non-zero net force acts on an object, the object will *accelerate* in the direction of the net force.
12. True
13. False. When a skater bumps into the boards in an arena, the skater exerts a force on the boards, and the boards exert an equal and opposite reaction force on the skater *at the same time.*
14. True
15. False. When a person walks on a rough surface, the frictional force exerted by the surface on the person is in the *same direction* as the person's motion.
16. False. When you are sliding down a hill on a snowboard, the normal force on you is *smaller* in magnitude than the force of gravity.
17. False. When two objects slip over each other, the force of the friction between them is called *kinetic* friction.
18. True
19. True

Understanding

20. Given: $m = 75\text{ kg}$; $\vec{a} = 2.0\text{ m/s}^2\text{ [up]}$

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

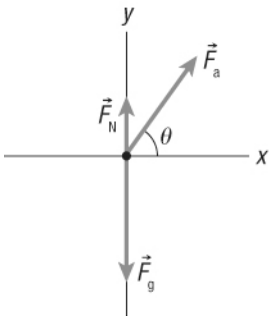
Analysis: $\Sigma\vec{F}_y = m\vec{a}$. Choose up as the positive direction.

Solution:

$$\begin{aligned}\Sigma\vec{F}_y &= m\vec{a}\\ \vec{F}_\text{N} - mg &= m\vec{a}\\ \vec{F}_\text{N} &= m(g+\vec{a})\\ &= (75\text{ kg})(2.0\text{ m/s}^2 + 9.8\text{ m/s}^2)\\ \vec{F}_\text{N} &= 8.8\times10^2\text{ N}\end{aligned}$$

Statement: The floor exerts a force of $8.8\times10^2\text{ N}$ [up] on the man when the elevator starts moving upward.

21. (a) The FBD of the suitcase is shown below.



(b) We know that the suitcase is moving at a constant speed, so the net force on the suitcase is zero. Choosing the direction of motion to be the +*x*-direction, the components of the net force are $\Sigma\vec{F}_x = 0\text{ N}$ and $\Sigma\vec{F}_y = 0\text{ N}$.

(c) Refer to the FBD to check the directions of the forces, choosing the +*x*-direction as the direction in which the handle is pointing. Both the force of gravity and the normal force are vertical, so their *x*-components are zero. Friction acts in the negative *x*-direction, so its *x*-component is negative. The applied force is at an angle, so we can use trigonometry to determine its *x*-component. The *x*-components of the forces can be expressed as follows: $\vec{F}_{gx} = 0\text{ N}$; $\vec{F}_{Nx} = 0\text{ N}$; $\vec{F}_{ax} = \vec{F}_a\cos\theta$; and $\vec{F}_{fx} = -\vec{F}_f$.

(d) The choice of +*x* that is more convenient is horizontally forward, because the positive *x*-direction is the direction of motion. Also, three of the four forces align with either the horizontal or vertical directions.

22. (a) A drop of rain falling with a constant speed has constant velocity and a net force of zero.

(b) A cork with a mass of 10 g floating on still water means that the cork is at rest, and that the net force is zero.

(c) A stone with a mass of 0.1 kg just after it is dropped from the window of a stationary train is acted upon by a net force equal to its weight. This is expressed as:

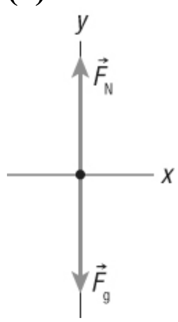
$$\begin{aligned}\Sigma\vec{F} &= mg\ [\text{down}]\\ &= (0.1\text{ kg})(9.8\text{ m/s}^2)\ [\text{down}].\\ \Sigma\vec{F} &= 1\text{ N [down]}\end{aligned}$$

(d) The same stone at rest on the floor of a train, which is accelerating at 1.0 m/s^2 is acted upon by a net force equal to the force of static friction pulling it forward with the train. This is expressed as:

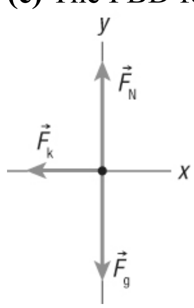
$$\begin{aligned}\Sigma\vec{F} &= m\vec{a}\ [\text{forward}]\\ &= (0.1\text{ kg})(1.0\text{ m/s}^2)\ [\text{forward}]\\ \Sigma\vec{F} &= 0.1\text{ N [forward]}\end{aligned}$$

23. (a) The FBD for a saucepan hanging from a hook is shown below.

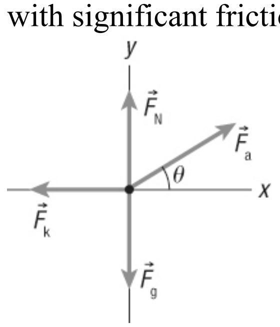
(b) The FBD for a person standing at rest on the floor is shown below.



(c) The FBD for a puck sliding in a straight line on the ice to the right is shown below.



(d) The FBD for a toboggan pulled by a rope at an angle above the horizontal to the right with significant friction on the toboggan is shown below.



24. The acceleration of the astronaut the instant he is outside the spaceship would be 0 m/s^2. Once outside the spacecraft, the astronaut continues to move at the velocity the spacecraft had as he exited. By Newton's first law of motion, no net force acts on the astronaut and so he does not accelerate.

25. Action and reaction forces cannot cancel each other, even though they are equal and opposite, because one force acts on one object and the other force acts on the second object. These forces do not cancel because they do not act on the same object.

26. Given: $m_A = 4.0 \text{ kg}; m_B = 6.0 \text{ kg}; \vec{F}_a = 20.0 \text{ N [E]}$
Required: $\vec{a}$
Analysis: $\Sigma\vec{F} = m\vec{a}$. Choose east as positive.
Solution: $\Sigma\vec{F} = m_T\vec{a}$

$$\vec{F}_a = m_T\vec{a}$$

$$\vec{a} = \frac{\vec{F}_a}{m_1 + m_2}$$

$$= \frac{20.0 \text{ N}}{10.0 \text{ kg}}$$

$$\vec{a} = 2.0 \text{ m/s}^2$$

Statement: The blocks accelerate at 2.0 m/s^2 [E].
27. The reading of the balance while it is in the air is 0 N, because there is no tension between its ends. The force of gravity acts on the spring balance, and it accelerates at the acceleration of gravity, with no other force acting upon it.
28. No, it is not always necessary for the coefficient of friction to be less than one. There are some materials with a coefficient of friction greater than one. Examples include sticky or tacky surfaces, wet packed snow on skis, or materials like Velcro®.
29. Answers may vary. Sample answer: Static friction may be useful on inclined planes for keeping objects in place; for example, a parked car does not slide away. Static friction is a problem on an inclined surface when you want to put an object in motion. For example, if I do not have the right wax on my cross-country skis, I will not slide downhill even if I lean forward. Kinetic friction is useful on an incline to keep objects moving at a constant speed; for example, with the right wax and the right incline, I can glide on my cross-country skis without accelerating. Kinetic friction is a problem on an incline if a great amount of acceleration is desired. For example, downhill ski racers want to accelerate quickly with their skis only gripping by the edges on the turns.
30. A linear actuator is a device that uses energy to apply a force. This force may lower the counter for a cashier, open or close power windows in cars, raise a workstation for an extremely tall worker, or lift a patient into a harness and onto a stretcher for transportation, or tighten the screws fastening the dashboard to a vehicle in an automobile assembly line. All of these tasks ease the effort a worker must give and so reduce the possibility of strain and injury.

Analysis and Application

31. A trebuchet applies the principles of linear motion by using the force of gravity to accelerate a large mass downward. The machine is constructed so that this forces the less massive arm to swing upwards with a high acceleration. The bucket holding the ammunition is even less massive and is swung with even higher acceleration. The bucket is angled to release the ammunition at a pre-calculated angle for the required angle of the projectile.
32. The force of reaction exerted by the block on the rope when the block is resting on a smooth horizontal surface is equal and opposite to the force of the rope on the block. The reaction force is 31.5 N.

33. Given: $m_{\text{H}} = 1.5 \times 10^3$ kg ; $m_{\text{P}} = 4.2 \times 10^2$ kg; $\vec{a} = 12$ m/s^2 [up]

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

Analysis: $\Sigma\vec{F}_y = m\vec{a}$. Choose up as positive.

Solution:

$$\begin{aligned} \Sigma\vec{F}_y &= m\vec{a} \\ \vec{F}_{\text{N}} - m_{\text{P}}g &= m_{\text{P}}\vec{a} \\ \vec{F}_{\text{N}} &= m_{\text{P}}(g + \vec{a}) \\ &= (420\text{ kg})(9.8\text{ m/s}^2 + 12\text{ m/s}^2) \\ \vec{F}_{\text{N}} &= 9.2 \times 10^3\text{N} \end{aligned}$$

Statement: The normal force exerted by the crew and passengers on the floor is 9.2×10^3 N [downward].

34. Given: $\vec{F}_{\text{A}} = 45$ N [*E*] ; $\vec{F}_{\text{B}} = 25$ N [N] ; $m = 23$ kg

Required: $\vec{a}$

Analysis: $\left|\Sigma\vec{F}\right| = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$; $\theta = \tan^{-1}\left(\dfrac{\Sigma\vec{F}_y}{\Sigma\vec{F}_x}\right)$. Choose east and north as positive.

Solution: For the *x*-components of the force:

$$\begin{aligned} \Sigma\vec{F}_x &= \vec{F}_{\text{A}x} + \vec{F}_{\text{B}x} \\ &= 25\text{ N} + 0\text{ N} \\ \Sigma\vec{F}_x &= 25\text{ N} \end{aligned}$$

For the *y*-components of the force:

$$\begin{aligned} \Sigma\vec{F}_y &= \vec{F}_{\text{A}y} + \vec{F}_{\text{B}y} \\ &= 0\text{ N} + 29\text{ N} \\ \Sigma\vec{F}_y &= 29\text{ N} \end{aligned}$$

Construct $\Sigma\vec{F}$:

$$\begin{aligned} \left|\Sigma\vec{F}\right| &= \sqrt{(\Sigma F_{\text{x}})^2 + (\Sigma F_{\text{y}})^2} \\ &= \sqrt{(45\text{ N})^2 + (29\text{ N})^2} \\ \left|\Sigma\vec{F}\right| &= 53.54\text{ N (two extra digits carried)} \end{aligned}$$

$$\begin{aligned} \theta &= \tan^{-1}\left(\frac{\Sigma\vec{F}_y}{\Sigma\vec{F}_x}\right) \\ &= \tan^{-1}\left(\frac{29\ \cancel{\text{N}}}{45\ \cancel{\text{N}}}\right) \\ \theta &= 33^\circ \end{aligned}$$

Solve for the acceleration, $\vec{a}$:

$$\Sigma\vec{F} = m\vec{a}$$

$$\vec{a} = \frac{\Sigma\vec{F}}{m}$$

$$= \frac{53.54 \text{ N [E } 33° \text{ N]}}{23 \text{ kg}}$$

$$\vec{a} = 2.3 \text{ m/s}^2 \text{ [E } 33° \text{ N]}$$

Statement: The object's acceleration is 2.3 m/s^2 [E 33° N].

35. Given: $\vec{F}_\text{A} = 47 \text{ N [E } 31° \text{ N]}$; $\vec{F}_\text{B} = 58 \text{ N [E } 46° \text{ N]}$; $\Sigma\vec{F} = 0 \text{ N}$

Required: $\vec{F}$; θ

Analysis: $\vec{F}_\text{A} + \vec{F}_\text{B} + \vec{F} = 0 \text{ N}$. Choose north and east as positive.

Solution: For the x-components of the force:

$$\vec{F}_{\text{A}x} + \vec{F}_{\text{B}x} + \vec{F}_x = 0$$

$$\vec{F}_x = -\vec{F}_{\text{A}x} - \vec{F}_{\text{B}x}$$

$$= -(47 \text{ N})\cos 31° - (58 \text{ N})\cos 46°$$

$$\vec{F}_x = -80.58 \text{ N (two extra digits carried)}$$

For the y-components of the force:

$$\vec{F}_{\text{A}y} + \vec{F}_{\text{B}y} + \vec{F}_y = 0$$

$$\vec{F}_y = -\vec{F}_{\text{A}y} - \vec{F}_{\text{B}y}$$

$$= -(47 \text{ N})\sin 31° - (58 \text{ N})\sin 46°$$

$$\vec{F}_y = -65.93 \text{ N (two extra digits carried)}$$

Construct $\vec{F}$:

$$\left|\vec{F}\right| = \sqrt{(F_x)^2 + (F_y)^2}$$

$$= \sqrt{(80.58 \text{ N})^2 + (65.93 \text{ N})^2}$$

$$= 100 \text{ N}$$

$$\left|\vec{F}\right| = 1.0 \times 10^2 \text{ N}$$

$$\theta = \tan^{-1}\left(\frac{\Sigma\vec{F}_y}{\Sigma\vec{F}_x}\right)$$

$$= \tan^{-1}\left(\frac{65.93 \cancel{\text{N}}}{80.58 \cancel{\text{N}}}\right)$$

$$\theta = 39°$$

Statement: $\vec{F}$ is 1.0×10^2 N [W 39° S].

36. (a) Given: $m_A = 2.3\text{ kg}; m_B = 3.5\text{ kg}; \vec{F}_{KA} = 5.4\text{ N}$

Required: $\vec{a}$

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: For block A (mass m_A):

$$\Sigma\vec{F}_x = m_A\vec{a}$$

$$\vec{F}_T - \vec{F}_K = m_A\vec{a}$$

For block B (mass m_B):

$$\Sigma\vec{F}_y = m_B\vec{a}$$

$$m_B g - \vec{F}_T = m_B\vec{a}$$

Add the final equations to eliminate the string tension.

Solving for $\vec{a}$:

$$\left(\vec{F}_T - \vec{F}_{KA}\right) + \left(m_B g - \vec{F}_T\right) = m_A\vec{a} + m_B\vec{a}$$

$$m_B g - \vec{F}_{KA} = (m_A + m_B)\vec{a}$$

$$\vec{a} = \frac{m_B g - F_{KA}}{m_A + m_B}$$

$$= \frac{(3.5\text{ kg})(9.8\text{ m/s}^2) - 5.4\text{ N}}{5.8\text{ kg}}$$

$$= 4.983\text{ m/s}^2 \text{ (two extra figures carried)}$$

$$\vec{a} = 5.0\text{ m/s}^2$$

Statement: The magnitude of acceleration of the blocks is 5.0 m/s^2.

(b) Given: $m_A = 2.3\text{ kg}; \vec{F}_{KA} = 5.4\text{ N}$

Required: $\vec{F}_T$

Analysis: $\vec{F}_T - \vec{F}_K = m_A\vec{a}$

Solution: $\vec{F}_T - \vec{F}_K = m_A\vec{a}$

$$\vec{F}_T = m_A\vec{a} + \vec{F}_K$$

$$= (2.3\text{ kg})(4.983\text{ m/s}^2) + 5.4\text{ N}$$

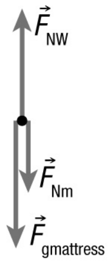
$$\vec{F}_T = 17\text{ N}$$

Statement: The magnitude of tension in the string is 17 N.

37. (a) The FBD for the man is shown below.

FBD for man

The FBD for the mattress is shown below.



FBD for mattress

(b) The reaction to the force of gravity on the man is an upward force of the man on Earth. The reaction to the force of gravity on the mattress is an upward force of the mattress on Earth. The normal force of the mattress on the man and the force of the man on the mattress are an action–reaction pair. The reaction force to the normal force of the water on the mattress is the mattress pushing down on the water.

(c) Given: $m_{\text{man}} = 1.1\times10^2\text{ kg}$; $m_{\text{mattress}} = 7.0\text{ kg}$; $\Sigma\vec{F}_{\text{mattress}} = 0\text{ N}$

Required: normal force of the water on the mattress, $\vec{F}_{\text{Nw}}$

Analysis: $\Sigma\vec{F} = 0\text{ N}$

Solution: $\vec{F}_{\text{Nw}} - \vec{F}_{\text{Nm}} - m_{\text{mattress}}g = 0\text{ N}$

$$\begin{aligned}\vec{F}_{\text{Nw}} &= \vec{F}_{\text{Nm}} + m_{\text{mattress}}g \\ &= (110\text{ kg})(9.8\text{ m/s}^2) + (7.0\text{ kg})(9.8\text{ m/s}^2) \\ &= 1078\text{ N} + 68.60\text{ N} \\ \vec{F}_{\text{Nw}} &= 1.1\times10^3\text{ N}\end{aligned}$$

Statement: The normal force of the water on the mattress is 1.1×10^3 N.

(d) Given: $m_{\text{man}} = 1.1\times10^2\text{ kg}$; $\Sigma\vec{F}_{\text{man}} = 0\text{ N}$

Required: normal force of the mattress on the man, $\vec{F}_{\text{Nm}}$

Analysis: $\Sigma\vec{F} = 0\text{ N}$

Solution: $\vec{F}_{\text{Nm}} - m_{\text{man}}g = 0\text{ N}$

$$\begin{aligned}\vec{F}_{\text{Nm}} &= m_{\text{man}}g \\ &= (110\text{ kg})(9.8\text{ m/s}^2) \\ \vec{F}_{\text{Nm}} &= 1.1\times10^3\text{ N}\end{aligned}$$

Statement: The normal force of the mattress on the man is 1.1×10^3 N.

38. Answers may vary. Sample answer: One version of Newton's first law of motion says that objects at rest tend to stay at rest. I can demonstrate this by setting a textbook on top of a piece of paper on a desk with a bit of the paper showing over the edge of the desk. If I suddenly pull horizontally on the paper, the book remains resting on the desk. The force of static friction between the paper and the book breaks so quickly, and the force of kinetic friction is so low, that the only force exerted on the textbook is a tiny external force, and so it hardly moves at all.

39. (a) Given: $\vec{F}_{\text{a}} = 1.2\times10^2\text{ N [E]} = 1.2\times10^5\text{ N [E]}$; $m = 42\text{ t} = 4.2\times10^4\text{ kg}$

Required: $\vec{a}$

Analysis: $\Sigma\vec{F} = m\vec{a}$. Choose east as the positive direction.

Solution: $\Sigma\vec{F} = m\vec{a}$

$$\begin{aligned}\vec{F}_{\text{a}} &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_{\text{a}}}{m} \\ &= \frac{1.2\times10^5\text{ N}}{4.2\times10^4\text{ kg}} \\ &= 2.857\text{ m/s}^2\text{ (two extra digits carried)} \\ \vec{a} &= 2.9\text{ m/s}^2\end{aligned}$$

Statement: The acceleration produced by the engines is 2.9 m/s^2 [E].

(b) Given: $\vec{a} = 2.9\text{ m/s}^2$; $v_{\text{i}} = 0\text{ m/s}$; $\vec{v}_{\text{f}} = 71\text{ m/s [E]}$

Required: Δd

Analysis: $\Delta d = \dfrac{v_{\text{f}}^2 - v_{\text{i}}^2}{2\vec{a}}$

Solution:

$$\begin{aligned}\Delta d &= \frac{v_{\text{f}}^2 - v_{\text{i}}^2}{2\vec{a}} \\ &= \frac{(71\text{ m/s})^2 - (0\text{ m/s})^2}{2(2.857\text{ m/s}^2)} \\ \Delta d &= 8.8\times10^2\text{ m}\end{aligned}$$

Statement: The minimum length of the runway needed is 8.8×10^2 m.

40. (a) Given: $m_1 = 1.3\text{ kg}$; $m_2 = 2.4\text{ kg}$; $\vec{F}_{\text{a}} = 8.6\text{ N [W]}$

Required: $\vec{a}$; $m_{\text{T}} = m_1 + m_2$

Analysis: $\Sigma\vec{F} = m\vec{a}$. Choose west as positive.

Solution: $m_\text{T} = m_1 + m_2$

$= 1.3 \text{ kg} + 2.4 \text{ kg}$

$m_\text{T} = 3.7 \text{ kg}$

$$\Sigma\vec{F} = m_\text{T}\vec{a}$$

$$\vec{F}_\text{a} = m_\text{T}\vec{a}$$

$$\vec{a} = \frac{\vec{F}_\text{a}}{m_\text{T}}$$

$$= \frac{8.6 \text{ N [W]}}{3.7 \text{ kg}}$$

$$= 2.324 \text{ m/s}^2 \text{ [W] (two extra digits carried)}$$

$$\vec{a} = 2.3 \text{ m/s}^2 \text{ [W]}$$

Statement: The acceleration of the masses is 2.3 m/s^2 [W].

(b) Given: $\vec{a} = 2.324 \text{ m/s}^2 \text{ [W]}$; $m_1 = 1.3 \text{ kg}$

Required: $\Sigma\vec{F}$

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: $\Sigma\vec{F} = m\vec{a}$

$= (1.3 \text{ kg})(2.324 \text{ m/s}^2 \text{ [W]})$

$\Sigma\vec{F} = 3.0 \text{ N [W]}$

Statement: The net force acting on the mass is 3.0 N [W].

41. (a) Given: $m_1 = 11 \text{ kg}; m_2 = 19 \text{ kg}$; $\vec{F}_\text{a} = 5.3 \times 10^2 \text{ N}$

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

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: $\Sigma\vec{F} = m_\text{T}\vec{a}$

$$\vec{F}_\text{a} = m_\text{T}\vec{a}$$

$$\vec{a} = \frac{\vec{F}_\text{a}}{m_\text{T}}$$

$$= \frac{530 \text{ N}}{30 \text{ kg}}$$

$$\vec{a} = 1.767 \text{ m/s}^2 \text{ (two extra digits carried)}$$

For mass m_2:

$$\Sigma\vec{F} = m_2\vec{a}$$

$$\vec{F}_\text{T} = (19 \text{ kg})(1.767 \text{ m/s}^2)$$

$$\vec{F}_\text{T} = 34 \text{ N}$$

Statement: The tension on the string when the applied force pulls directly on the 11 kg mass is 34 N.

(b) Given: $m_1 = 11$ kg; $\vec{a} = 1.767$ m/s^2

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

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: $\Sigma\vec{F} = m_1\vec{a}$

$$\vec{F}_\text{T} = (11 \text{ kg})(1.767 \text{ m/s}^2)$$

$$\vec{F}_\text{T} = 19 \text{ N}$$

Statement: The tension on the string when the applied force pulls directly on the 19 kg mass is 19 N.

42. (a) Given: $m = 2.5$ kg; $\vec{F}_\text{air} = 12$ N [right]; $\Sigma\vec{F} = 0$ N

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

Analysis: $\Sigma\vec{F} = 0$ N ; $\left|\vec{F}_\text{T}\right| = \sqrt{(\vec{F}_{\text{T}x})^2 + (\vec{F}_{\text{T}y})^2}$. Choose right and up as positive.

Solution: For the x-components of the force:

$$\begin{aligned}
\Sigma\vec{F}_x &= 0 \text{ N} \\
\vec{F}_{\text{T}x} + \vec{F}_\text{air} &= 0 \text{ N} \\
\vec{F}_{\text{T}x} &= -\vec{F}_\text{air} \\
\vec{F}_{\text{T}x} &= -12 \text{ N}
\end{aligned}$$

For the y-components of the force:

$$\begin{aligned}
\Sigma\vec{F}_y &= 0 \text{ N} \\
\vec{F}_{\text{T}y} - mg &= 0 \text{ N} \\
\vec{F}_{\text{T}y} &= mg \\
&= (2.5 \text{ kg})(9.8 \text{ m/s}^2) \\
\vec{F}_{\text{T}y} &= 24.5 \text{ N (one extra digit carried)}
\end{aligned}$$

Construct $\vec{F}_\text{T}$ from its components:

$$\begin{aligned}
\left|\vec{F}_\text{T}\right| &= \sqrt{(F_{\text{T}x})^2 + (F_{\text{T}y})^2} \\
&= \sqrt{(12 \text{ N})^2 + (24.5 \text{ N})^2} \\
&= 27.28 \text{ N} \\
\left|\vec{F}_\text{T}\right| &= 27 \text{ N}
\end{aligned}$$

Statement: The tension in the rope is 27 N.

(b) Given: $\vec{F}_{\text{T}x} = -12$ N ; $\vec{F}_{\text{T}y} = 24.5$ N

Required: θ

Analysis: $\theta = \tan^{-1}\left(\dfrac{\vec{F}_{\text{T}y}}{\vec{F}_{\text{T}x}}\right)$. Choose right and up as positive.

Solution: $\theta = \tan^{-1}\left(\dfrac{\vec{F}_{\text{T}y}}{\vec{F}_{\text{T}x}}\right)$

$$= \tan^{-1}\left(\frac{24.5\ \cancel{\text{N}}}{12\ \cancel{\text{N}}}\right)$$

$$\theta = 64^\circ$$

Statement: The rope makes an angle of 64° with the horizontal.

43. (a) Given: $m = 54$ kg; $\theta = 35.0^\circ$

Required: tension in horizontal rope, $\vec{F}_{\text{T1}}$; tension in vertical rope, $\vec{F}_{\text{T2}}$

Analysis: $\Sigma\vec{F} = 0$ N

Solution: For the y-components of the force:

$$\vec{F}_{\text{T2}y} - mg = 0 \text{ N}$$

$$\vec{F}_{\text{T2}y} = mg$$

$$\vec{F}_{\text{T2}} = \frac{mg}{\sin\theta}$$

$$= \frac{(54 \text{ kg})(9.8 \text{ m/s}^2)}{\sin 35.0^\circ}$$

$$= 922.6 \text{ N (two extra digits carried)}$$

$$\vec{F}_{\text{T2}} = 9.2 \times 10^2 \text{ N}$$

For the x-components of the force:

$$\vec{F}_{\text{T1}x} + \vec{F}_{\text{T2}x} = 0 \text{ N}$$

$$-\vec{F}_{\text{T1}} + \vec{F}_{\text{T2}}\cos\theta = 0 \text{ N}$$

$$\vec{F}_{\text{T1}} = \vec{F}_{\text{T2}}\cos\theta$$

$$= (922.6 \text{ N})\cos 35.0^\circ$$

$$\vec{F}_{\text{T1}} = 7.6 \times 10^2 \text{ N}$$

Statement: The tension in the horizontal rope is 7.6×10^2 N, and the tension in the vertical rope is 9.2×10^2 N.

(b) If the horizontal rope were slightly longer and attached to the wall at a higher point, its tension would have a vertical component supporting some of the weight of the performer. As a result the tension in the second rope would be reduced. This means the horizontal component of the first tension would also be reduced. As long as the angle of the first rope with the horizontal is small, the tension in the first rope would be reduced as well.

44. Given: $m = 65$ kg; $\vec{v} = 25$ m/s [S]; $\vec{F}_{\text{a}} = 1.2 \times 10^3$ N [S]

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

Analysis: $\Sigma\vec{F} = 0$ N; $\vec{F}_{\text{w}} = \vec{F}_{\text{N}} + \vec{F}_{\text{f}}$. Choose south and up as positive.

Solution: For the *y*-components of the force:

$$\Sigma \vec{F}_y = 0 \text{ N}$$
$$\vec{F}_\text{N} - mg = 0 \text{ N}$$
$$\vec{F}_\text{N} = mg$$
$$= (65 \text{ kg})(9.8 \text{ m/s}^2)$$
$$\vec{F}_\text{N} = 637 \text{ N (one extra digit carried)}$$

For the *x*-components of the force:

$$\Sigma \vec{F}_x = 0 \text{ N}$$
$$\vec{F}_\text{a} - \vec{F}_\text{f} = 0 \text{ N}$$
$$\vec{F}_\text{f} = \vec{F}_\text{a}$$
$$\Sigma \vec{F}_x = 1200 \text{ N (two extra digits carried)}$$

Construct $\vec{F}_\text{w}$:

$$\left|\vec{F}_\text{w}\right| = \sqrt{(\vec{F}_\text{N})^2 + (\vec{F}_\text{f})^2}$$
$$= \sqrt{(637 \text{ N})^2 + (1200 \text{ N})^2}$$
$$\left|\vec{F}_\text{w}\right| = 1.4 \times 10^3 \text{ N}$$

$$\theta = \tan^{-1}\left(\frac{\vec{F}_\text{N}}{\vec{F}_\text{f}}\right)$$
$$= \tan^{-1}\left(\frac{637 \cancel{\text{N}}}{1200 \cancel{\text{N}}}\right)$$
$$\theta = 28°$$

Statement: The force of the water on the skier's ski is 1.4 × 10^3 N [N 28° up].

45. Given: $m = 160 \text{ g} = 0.16 \text{ kg}$; $v_\text{i} = 0 \text{ m/s}$; $v_\text{f} = 32 \text{ m/s}$; $\Delta t = 0.011 \text{ s}$

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

Analysis: $\Sigma \vec{F} = m\vec{a}$. Choose forward and up as positive.

Solution: $\vec{a} = \dfrac{v_\text{f} - v_\text{i}}{\Delta t}$

$$= \frac{(32 \text{ m/s}) - (0 \text{ m/s})}{0.011 \text{ s}}$$
$$\vec{a} = 2909 \text{ m/s}^2 \text{ (two extra digits carried)}$$

Determine the net force:

$$\Sigma\vec{F}_x = ma$$
$$\vec{F}_\text{a} = ma$$
$$= (0.160\text{ kg})(2909\text{ m/s}^2)$$
$$\vec{F}_\text{a} = 4.7\times10^2\text{ N}$$

Statement: The magnitude of the force applied to the puck is 4.7 × 10^2 N.

46. Given: $\vec{F}_\text{a} = 1.7\times10^4\text{ N}$; $\vec{a} = 6.9\text{ m/s}^2$

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

Analysis: $\Sigma\vec{F} = m\vec{a}$. Choose up as the positive direction.

Solution: In deep space:

$$\Sigma\vec{F} = m\vec{a}$$
$$\vec{F}_\text{a} = m\vec{a}$$
$$m = \frac{\vec{F}_\text{a}}{\vec{a}}$$
$$= \frac{1.7\times10^4\text{ N}}{6.9\text{ m/s}^2}$$
$$m = 2.464\times10^3\text{ kg (two extra digits carried)}$$

On Earth:

$$\Sigma\vec{F} = m\vec{a}$$
$$\vec{F}_\text{a} - mg = m\vec{a}$$
$$\vec{F}_\text{a} = m(g+\vec{a})$$
$$= (2.464\times10^3\text{ kg})(9.8\text{ m/s}^2 + 6.9\text{ m/s}^2)$$
$$\vec{F}_\text{a} = 4.1\times10^4\text{ N}$$

Statement: A force of 4.1 × 10^4 N is required for the spacecraft to accelerate at the same rate upward from Earth.

47. Given: $m_1 = 6.0\text{ kg}$; $m_2 = 4.0\text{ kg}$; $m_3 = 3.0\text{ kg}$

Required: $\vec{a}$; $\vec{F}_\text{TA}$; $\vec{F}_\text{TB}$

Analysis: $\Sigma\vec{F} = m\vec{a}$

Equation for mass m_1:

$$\Sigma\vec{F} = m_1\vec{a}$$
$$\vec{F}_\text{TA} - m_1 g = m_1\vec{a}$$

Equation for mass m_2:

$$\Sigma\vec{F} = m_2\vec{a}$$
$$-\vec{F}_\text{TA} + \vec{F}_\text{TB} + m_2 g = m_2\vec{a}$$

Equation for mass m_3:

$$\Sigma \vec{F} = m_3 \vec{a}$$

$$-\vec{F}_{\text{TB}} + m_3 g = m_3 \vec{a}$$

We can now add the three equations above to solve for $\vec{a}$.

$$-m_1 g + m_2 g + m_3 g = (m_1 + m_2 + m_3)\vec{a}$$

$$\vec{a} = \frac{(-m_1 + m_2 + m_3)g}{m_1 + m_2 + m_3}$$

Solution: $\vec{a} = \dfrac{(-m_1 + m_2 + m_3)g}{m_1 + m_2 + m_3}$

$$= \frac{(-6.0\ \cancel{\text{kg}} + 4.0\ \cancel{\text{kg}} + 3.0\ \cancel{\text{kg}})9.8\ \text{m/s}^2}{6.0\ \cancel{\text{kg}} + 4.0\ \cancel{\text{kg}} + 3.0\ \cancel{\text{kg}}}$$

$= 0.7538\ \text{m/s}^2$ (two extra digits carried)

$\vec{a} = 0.75\ \text{m/s}^2$

Substitute in the equation for mass m_1:

$$\vec{F}_{\text{TA}} - m_1 g = m_1 \vec{a}$$

$$\vec{F}_{\text{TA}} = m_1 (g + \vec{a})$$

$$= (6.0\ \text{kg})(9.8\ \text{m/s}^2 + 0.7538\ \text{m/s}^2)$$

$$\vec{F}_{\text{TA}} = 63\ \text{N}$$

Substitute in the equation for mass m_3:

$$-\vec{F}_{\text{TB}} + m_3 g = m_3 \vec{a}$$

$$\vec{F}_{\text{TB}} = m_3 (g - \vec{a})$$

$$= (3.0\ \text{kg})(9.8\ \text{m/s}^2 - 0.7538\ \text{m/s}^2)$$

$$\vec{F}_{\text{TB}} = 27\ \text{N}$$

Statement: The acceleration of the system is $0.75\ \text{m/s}^2$. The tension in string A is 63 N, and the tension in string B is 27 N.

48. Given: $m = 60.0\ \text{kg}$; direction of $\vec{F}_{\text{T1}}$ is [up 15° left];
direction of $\vec{F}_{\text{T2}}$ is [up 15° right]

Required: $\vec{F}_{\text{T}} \left(= \left|\vec{F}_{\text{T1}}\right| = \left|\vec{F}_{\text{T2}}\right| \right)$

Analysis: $\Sigma \vec{F} = 0\ \text{N}$

Solution: For the x-components of the force:

$$\Sigma \vec{F}_x = \vec{F}_{gx} + \vec{F}_{1x} + \vec{F}_{2x}$$

$$0\ \text{N} = (0\ \text{N}) - \vec{F}_{\text{T1}} \cos 15° + \vec{F}_{\text{T2}} \cos 15°$$

$$\vec{F}_{\text{T1}} = \vec{F}_{\text{T2}}$$

For the y-components of the force:

$$\Sigma\vec{F}_y = \vec{F}_{gy} + \vec{F}_{1y} + \vec{F}_{2y}$$
$$0 \text{ N} = -mg + \vec{F}_{T1}\sin 15° + \vec{F}_{T2}\sin 15°$$
$$0 \text{ N} = -(60.0 \text{ kg})(9.8 \text{ m/s}^2) + 2\vec{F}_T \sin 15°$$
$$\vec{F}_T = \frac{(60.0 \text{ kg})(9.8 \text{ m/s}^2)}{2\sin 15°}$$
$$\vec{F}_T = 1.1\times10^3 \text{ N}$$

Statement: The tension in the rope on both sides of the tightrope walker is $F_T = 1.1\times10^3 \text{ N}$.

49. Given: $m_2 = 22 \text{ kg}$; $\mu_K = 0.35$

Required: $\vec{F}_N$

Analysis: $\Sigma\vec{F} = 0 \text{ N}$. The forces on crate 2 (mass m_2) include the force of gravity, the normal force of the floor, kinetic friction and the horizontal normal force from crate 1 (mass m_1). For crate 2, it is the horizontal normal force that counters the kinetic friction.

Solution: For the y-components of the force (mass m_2):

$$\Sigma\vec{F}_y = 0 \text{ N}$$
$$\vec{F}_{N2} - m_2 g = 0 \text{ N}$$
$$\vec{F}_{N2} = m_2 g$$
$$= (22 \text{ kg})(9.8 \text{ m/s}^2)$$
$$\vec{F}_{N2} = 215.6 \text{ N (two extra digits carried)}$$

For the x-components of the force (mass m_2):

$$\Sigma\vec{F}_x = 0 \text{ N}$$
$$\vec{F}_N - \vec{F}_{K2} = 0 \text{ N}$$
$$\vec{F}_N = \vec{F}_{K2}$$
$$= \mu_K \vec{F}_{N2}$$
$$= 0.35(215.6 \text{ N})$$
$$\vec{F}_N = 75 \text{ N}$$

Statement: The magnitude of the normal force between the two crates is 75 N.

50. (a) Given: $\vec{F}_a = 2.2\times10^5 \text{ N [right 35° down]}$; $\vec{a} = 0.62 \text{ m/s}^2 \text{ [right]}$; $\vec{F}_f = 1.4\times10^2 \text{ N [left]}$

Required: m

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: For the *x*-components of the force:

$$\Sigma\vec{F}_x = m\vec{a}$$

$$\vec{F}_\text{a}\cos\theta - \vec{F}_\text{f} = m\vec{a}$$

$$m = \frac{\vec{F}_\text{a}\cos\theta - \vec{F}_\text{f}}{a}$$

$$= \frac{(220\text{ N})\cos 35° - 140\text{ N}}{0.62\text{ m/s}^2}$$

$$= 64.82\text{ kg (two extra digits carried)}$$

$$m = 65\text{ kg}$$

Statement: The total mass of the chair and person is 65 kg.

(b) Given: $m = 64.82\text{ kg}$; $\vec{F}_\text{a} = 2.2\times10^5\text{ N [right 35° down]}$

Required: F_N

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: Equation for the *y*-components:

$$\Sigma\vec{F}_y = 0\text{ N}$$

$$\vec{F}_\text{N} - \vec{F}_\text{a}\sin\theta - mg = 0\text{ N}$$

$$\vec{F}_\text{N} = \vec{F}_\text{a}\sin\theta + mg$$

$$= (220\text{ N})\sin 35° + 761(64.82\text{ kg})(9.8\text{ m/s}^2)$$

$$\vec{F}_\text{N} = 7.6\times10^2\text{ N}$$

Statement: The normal force acting on the chair is 7.6 × 10^2 N.

51. Given: $\mu_\text{S} = 0.25$; $m = 1.3\times10^2\text{ kg}$

Required: F_a

Analysis: $\Sigma\vec{F} = 0\text{ N}$; $\vec{F}_\text{S max} = \mu_\text{S}\vec{F}_\text{N}$

Solution: For the *y*-components of the force:

$$\Sigma\vec{F}_y = 0\text{ N}$$

$$\vec{F}_\text{N} - mg = 0\text{ N}$$

$$\vec{F}_\text{N} = mg$$

$$= (130\text{ kg})(9.8\text{ m/s}^2)$$

$$\vec{F}_\text{N} = 1274\text{ N (two extra digits carried)}$$

For the x-components of the force:

$$\Sigma\vec{F}_x = 0 \text{ N}$$
$$\vec{F}_a - \vec{F}_S = 0 \text{ N}$$
$$\vec{F}_a = \vec{F}_S$$
$$= \mu_s \vec{F}_N$$
$$= 0.25(1274 \text{ N})$$
$$\vec{F}_a = 3.2 \times 10^2 \text{ N}$$

Statement: The magnitude of the minimum force required is 3.2×10^2 N.

52. (a) Given: $m = 85$ kg**;** $\vec{F}_a = 3.3 \times 10^2$ N

Required: μ_S

Analysis: $\Sigma\vec{F} = 0$ N ; $\vec{F}_S = \mu_S \vec{F}_N$

Solution: For the y-components of the force:

$$\Sigma\vec{F}_y = 0 \text{ N}$$
$$\vec{F}_N - mg = 0 \text{ N}$$
$$\vec{F}_N = mg$$

For the x-components of the force:

$$\Sigma\vec{F}_x = 0 \text{ N}$$
$$\vec{F}_a - \vec{F}_S = 0 \text{ N}$$
$$\vec{F}_S = \vec{F}_a$$
$$\mu_S \vec{F}_N = \vec{F}_a$$
$$\mu_S = \frac{\vec{F}_a}{mg}$$
$$= \frac{330 \cancel{\text{N}}}{(85 \cancel{\text{kg}})(9.8 \cancel{\text{m/s}^2})}$$
$$\mu_S = 0.40$$

Statement: The coefficient of static friction between the floor and the trunk is 0.40.

(b) Given: $v_f = 2.0$ m/s; $\Delta t = 5.0$ s ; $\vec{F}_a = 3.3 \times 10^2$ N ; $m = 85$ kg

Required: μ_K

Analysis: $\Sigma\vec{F} = m\vec{a}$

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

$$= \frac{2.0 \text{ m/s}}{5.0 \text{ s}}$$
$$\vec{a} = 0.40 \text{ m/s}^2$$

Use the x-components of the forces:

$$\Sigma\vec{F}_x = m\vec{a}$$
$$\vec{F}_\text{a} - \vec{F}_\text{K} = m\vec{a}$$
$$\vec{F}_\text{K} = \vec{F}_\text{a} - m\vec{a}$$
$$\mu_\text{K}\vec{F}_\text{N} = \vec{F}_\text{a} - m\vec{a}$$
$$\mu_\text{K} = \frac{\vec{F}_\text{a} - m\vec{a}}{mg}$$
$$= \frac{330\ \text{N} - (85\ \cancel{\text{kg}})(0.40\ \cancel{\text{m/s}^2})}{(85\ \cancel{\text{kg}})(9.8\ \cancel{\text{m/s}^2})}$$
$$\mu_\text{K} = 0.36$$

Statement: The coefficient of kinetic friction is 0.36.

53. Given: $\vec{a} = 4.0\ \text{m/s}^2$ [forward]

Required: μ_S

Analysis: $\Sigma\vec{F}_x = m\vec{a}$

Solution:

Equation for x-component of motion:

$$\Sigma\vec{F}_x = m\vec{a}$$
$$\vec{F}_{\text{S max}} = m\vec{a}$$
$$\mu_\text{S} mg = m\vec{a}$$
$$\mu_\text{S} = \frac{\vec{a}}{g}$$
$$= \frac{4.0\ \cancel{\text{m/s}^2}}{9.8\ \cancel{\text{m/s}^2}}$$
$$\mu_\text{S} = 0.41$$

Statement: The coefficient of static friction between the driver's tires and the road is 0.41.

54. Given: $v_\text{i} = 35\ \text{m/s}; v_\text{f} = 0\ \text{m/s}; \Delta d = 95\ \text{m}$

Required: μ_K

Analysis: $v_\text{f}^2 = v_\text{i}^2 + 2\vec{a}\Delta d$. Choose forward as positive.

Solution: Determine the acceleration, $\vec{a}$:

$$v_f^2 = v_i^2 + 2\vec{a}\Delta d$$

$$\vec{a} = -\frac{v_i^2}{2\Delta d}$$

$$= -\frac{(35\ \text{m/s})^2}{2(95\ \text{m})}$$

$$\vec{a} = -6.447\ \text{m/s}^2 \text{ (two extra digits carried)}$$

Calculate μ_K :

$$\Sigma\vec{F}_x = m\vec{a}$$

$$-\vec{F}_K = m\vec{a}$$

$$-\mu_K \cancel{m} g = \cancel{m}\vec{a}$$

$$\mu_K = -\frac{\vec{a}}{g}$$

$$= \frac{6.447\ \cancel{\text{m/s}^2}}{9.8\ \cancel{\text{m/s}^2}}$$

$$\mu_K = 0.66$$

Statement: The coefficient of kinetic friction between the puck and the ice is 0.66.

55. Given: $m = 2.4$ kg; $\vec{F}_a = 450$ N [down]; $\mu_S = 0.67$

Required: $\vec{F}_N$

Analysis: $\vec{F}_S = \mu_S \vec{F}_N$; $\Sigma\vec{F}_y = 0$ N

Solution:

Equation for y-direction:

$$\Sigma\vec{F}_y = 0\ \text{N}$$

$$2\vec{F}_S - mg - \vec{F}_a = 0\ \text{N}$$

$$\vec{F}_S = \frac{mg + \vec{F}_a}{2}$$

$$= \frac{(2.4\ \text{kg})(9.8\ \text{m/s}^2) + 450\ \text{N}}{2}$$

$$\vec{F}_S = 236.8\ \text{N (two extra digits carried)}$$

Use the breaking value of static friction to solve for the normal force:

$$\vec{F}_S = \mu_S \vec{F}_N$$

$$\vec{F}_N = \frac{\vec{F}_S}{\mu_S}$$

$$= \frac{236.8 \text{ N}}{0.67}$$

$$\vec{F}_N = 3.5 \times 10^2 \text{ N}$$

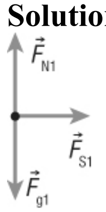
Statement: Each jaw of the vise exerts a horizontal normal force of 3.5×10^2 N on the block.

56. Given: $m_1 = 15$ kg (Crate 1); $m_2 = 35$ kg (Crate 2); $\vec{a} = 1.7 \text{ m/s}^2$; $g = 9.8 \text{ m/s}^2$

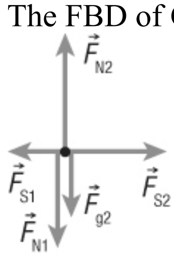
Required: $\vec{F}_{S1}$; $\vec{F}_{N1}$; $\vec{F}_{g1}$; $\vec{F}_{S2}$; $\vec{F}_{N2}$; $\vec{F}_{g2}$

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: The FBD of Crate 1 is shown below.



The FBD of Crate 2 is shown below.



For the *x*-components of the force (Crate 1):

$$\Sigma\vec{F}_x = m_1\vec{a}$$

$$\vec{F}_{S1} = m_1\vec{a}$$

$$= (15 \text{ kg})(1.7 \text{ m/s}^2)$$

$$\vec{F}_{S1} = 25 \text{ N}$$

For the y-components of the force (Crate 1):

$$\Sigma\vec{F}_y = 0\text{ N}$$
$$\vec{F}_{\text{N1}} - m_1 g = 0\text{ N}$$
$$\vec{F}_{\text{N1}} = m_1 g$$
$$= (15\text{ kg})(9.8\text{ m/s}^2)$$
$$= 147\text{ N (one extra digit carried)}$$
$$\vec{F}_{\text{N1}} = 1.5\times 10^2\text{ N}$$

For the x-components of the force (Crate 2):

$$\Sigma\vec{F}_x = m_2\vec{a}$$
$$\vec{F}_{\text{S2}} - \vec{F}_{\text{S1}} = m_2\vec{a}$$
$$\vec{F}_{\text{S2}} = \vec{F}_{\text{S1}} + m_2\vec{a}$$
$$= (25.5\text{ N}) + (35\text{ kg})(1.7\text{ m/s}^2)$$
$$\vec{F}_{\text{S2}} = 85\text{ N}$$

For the y-components of the force (Crate 2):

$$\Sigma\vec{F}_y = 0\text{ N}$$
$$\vec{F}_{\text{N2}} - \vec{F}_{\text{N1}} - m_2 g = 0\text{ N}$$
$$\vec{F}_{\text{N2}} = \vec{F}_{\text{N1}} + m_2 g$$
$$= 147\text{ N} + (35\text{ kg})(9.8\text{ m/s}^2)$$
$$= 147\text{ N } + 343\text{ N}$$
$$= 490\text{ N}$$
$$\vec{F}_{\text{N2}} = 4.9\times 10^2\text{ N}$$

Force of gravity on Crate 2:

$$\vec{F}_{\text{g2}} = m_2 g$$
$$= 35\text{ kg}(9.8\text{ m/s}^2)$$
$$\vec{F}_{\text{g2}} = 3.4\times 10^2\text{ N}$$

Statement: The normal force on Crate 1, $\vec{F}_{\text{N1}}$, is 1.5×10^2 N, which is the same as the force of gravity, $\vec{F}_{\text{g1}}$. The static friction action–reaction pair of forces between Crate 1 and Crate 2, $\vec{F}_{\text{S1}}$, is 25 N. The force of gravity on Crate 2, $\vec{F}_{\text{g2}}$, is 3.4×10^2 N. The normal force between Crate 2 and the truck, $\vec{F}_{\text{N2}}$, is 4.9×10^2 N. The static friction between Crate 2 and the truck, $\vec{F}_{\text{S2}}$, is 85 N.

57. (a) Given: $\mu = 0.70$; $m = 2.0\text{ kg}$; $\theta = 32°$

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

Analysis: The following forces are acting on the block: force of gravity [down], normal force [up perpendicular to plane], force of friction [up parallel to the plane]. The force of friction must act up the plane because the force of gravity pulls the block down the plane.

If the block does not move, there is no net force and the friction is static. If the block moves at all, it will move down the plane and the friction is kinetic. In either case, the magnitude of the force of friction is less than the component of gravity down the plane. Write out the net force in components and then calculate the normal force and the component of gravity along the plane. Compare the magnitude of the force of gravity along the plane with μF_N.

Solution: y-direction of net force:

$$\Sigma\vec{F}_y = 0\ \mathrm{N}$$

$$\vec{F}_\mathrm{N} - mg\cos\theta = 0\ \mathrm{N}$$

$$\vec{F}_\mathrm{N} = mg\cos\theta$$

$$= (2.0\ \mathrm{kg})(9.8\ \mathrm{m/s^2})\cos 32°$$

$$\vec{F}_\mathrm{N} = 16.62\ \mathrm{N}\ \text{(two extra digits carried)}$$

x-component of force of gravity:

$$\Sigma\vec{F}_x = 0\ \mathrm{N}$$

$$\vec{F}_\mathrm{N} - mg\sin\theta = 0\ \mathrm{N}$$

$$\vec{F}_\mathrm{N} = mg\sin\theta$$

$$mg\sin\theta = (2.0\ \mathrm{kg})(9.8\ \mathrm{m/s^2})\sin 32°$$

$$\vec{F}_\mathrm{N} = 10\ \mathrm{N}$$

maximum value of $\vec{F}_\mathrm{f}$:

$$\mu\vec{F}_\mathrm{N} = 0.70(16.62\ \mathrm{N})$$

$$= 11.63\ \mathrm{N}$$

$$\mu\vec{F}_\mathrm{N} = 12\ \mathrm{N}$$

Since $\mu\vec{F}_\mathrm{N}$ is greater than $mg\sin\theta$, the force of friction must just balance the force of gravity along the plane, $\vec{F}_\mathrm{f} = 10\ \mathrm{N}$ [up the plane].

Statement: The force of friction acting on the block is 10 N [up the plane].

(b) Since F_f is less than μF_N, the force of friction is static.

58. Given: $\mu_\mathrm{S} = 0.45$; $m = 66\ \mathrm{kg}$

Required: $\vec{F}_\mathrm{a}$

Analysis: $\vec{F}_\mathrm{S} = \mu_\mathrm{S}\vec{F}_\mathrm{N}$; $\Sigma\vec{F} = 0\ \mathrm{N}$

Solution: For the y-components of the force:

$$\Sigma\vec{F}_y = 0\ \mathrm{N}$$

$$\vec{F}_\mathrm{N} - mg = 0\ \mathrm{N}$$

$$\vec{F}_\mathrm{N} = mg$$

$$= (66\ \mathrm{kg})(9.8\ \mathrm{m/s^2})$$

$$\vec{F}_\mathrm{N} = 646.8\ \mathrm{N}\ \text{(two extra digits carried)}$$

$$\begin{aligned}
\Sigma\vec{F}_x &= 0\text{ N} \\
\vec{F}_\text{a} - \vec{F}_\text{S} &= 0\text{ N} \\
\vec{F}_\text{a} &= \vec{F}_\text{S} \\
&= \mu_\text{s}\vec{F}_\text{N} \\
&= 0.45(646.8\text{ N}) \\
\vec{F}_\text{a} &= 2.9\times 10^2\text{ N}
\end{aligned}$$

Statement: The minimum horizontal force that a person must apply is 2.9×10^2 N.

59. Given: $\theta = 26°$; $\vec{a} = \dfrac{g}{5} = 1.96\text{ m/s}^2$

Required: μ_K

Analysis: $\Sigma\vec{F} = m\vec{a}$.

Solution: For the y-components of the force:

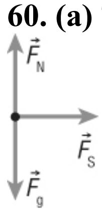
$$\begin{aligned}
\Sigma\vec{F}_y &= 0\text{ N} \\
\vec{F}_\text{N} - mg\cos\theta &= 0\text{ N} \\
\vec{F}_\text{N} &= mg\cos\theta
\end{aligned}$$

For the x-components of the force:

$$\begin{aligned}
\Sigma\vec{F}_x &= m\vec{a} \\
mg\sin\theta - \vec{F}_\text{K} &= m\vec{a} \\
\vec{F}_\text{K} &= mg\sin\theta - m\vec{a} \\
\mu_\text{K} mg\cos\theta &= mg\sin\theta - m\left(\frac{g}{5}\right) \\
\mu_\text{K} &= \frac{\cancel{mg}\left(\sin 26° - \dfrac{1}{5}\right)}{\cancel{mg}\cos 26°} \\
\mu_\text{K} &= 0.27
\end{aligned}$$

Statement: The coefficient of kinetic friction is 0.27.

60. (a) The FBD of the person is shown below.



(b) Given: $\mu_\text{S} = 0.43$

Required: $\vec{a}$

Analysis: $F_\text{S} = \mu_\text{S} F_\text{N}$; $\Sigma\vec{F} = m\vec{a}$

Solution: For the *y*-components of the force:

$$\Sigma\vec{F}_y = 0\text{ N}$$
$$\vec{F}_\text{N} - mg = 0\text{ N}$$
$$\vec{F}_\text{N} = mg$$

For the *x*-components of the force:

$$\Sigma\vec{F}_x = m\vec{a}$$
$$\vec{F}_\text{S} = m\vec{a}$$
$$\mu_\text{S}\vec{F}_\text{N} = m\vec{a}$$
$$\mu_\text{S}\cancel{m}g = \cancel{m}\vec{a}$$
$$\vec{a} = \mu_\text{S}g$$
$$= 0.43(9.8\text{ m/s}^2)$$
$$\vec{a} = 4.2\text{ m/s}^2$$

Statement: The maximum acceleration of the train before the person starts to slip is 4.2 m/s^2.

(c) Answers may vary. Sample answer: To keep from slipping, the passenger can push down on the ground to increase the normal force**.**

61. Given: $\mu_\text{S} = 0.16$

Required: $\vec{a}$

Analysis: $\vec{F}_\text{S} = \mu_\text{S}\vec{F}_\text{N}$

Solution: For the *y*-components of the force:

$$\Sigma\vec{F}_y = 0\text{ N}$$
$$\vec{F}_\text{N} - mg = 0\text{ N}$$
$$\vec{F}_\text{N} = mg$$

For the *x*-components of the force:

$$\Sigma\vec{F}_x = m\vec{a}$$
$$\vec{F}_\text{S} = m\vec{a}$$
$$\mu_\text{S}\vec{F}_\text{N} = m\vec{a}$$
$$\mu_\text{S}\cancel{m}g = \cancel{m}\vec{a}$$
$$\vec{a} = \mu_\text{S}g$$
$$= 0.16(9.8\text{ m/s}^2)$$
$$\vec{a} = 1.6\text{ m/s}^2$$

Statement: The maximum acceleration of the train that will allow the box to remain stationary is 1.6 m/s^2.

62. Given: $a = 2.5 \text{ m/s}^2$; $\theta = 26°$

Required: μ_K

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: For the *y*-components of the force:

$$\begin{aligned} \Sigma\vec{F}_y &= 0 \text{ N} \\ \vec{F}_\text{N} - mg\cos\theta &= 0 \text{ N} \\ \vec{F}_\text{N} &= mg\cos\theta \end{aligned}$$

For the *x*-components of the force:

$$\begin{aligned} \Sigma\vec{F}_x &= m\vec{a} \\ mg\sin\theta - \vec{F}_\text{K} &= m\vec{a} \\ mg\sin\theta - \mu_\text{K}\vec{F}_\text{N} &= m\vec{a} \\ mg\sin\theta - \mu_\text{K}mg\cos\theta &= m\vec{a} \\ \mu_\text{K} &= \frac{g\sin\theta - \vec{a}}{g\cos\theta} \\ &= \frac{\left(9.8 \cancel{\text{ m/s}^2}\right)\sin 26° - 2.5 \cancel{\text{ m/s}^2}}{\left(9.8 \cancel{\text{ m/s}^2}\right)\cos 26°} \\ \mu_\text{K} &= 0.20 \end{aligned}$$

Statement: The coefficient of kinetic friction between the block and the incline is 0.20.

63. Given: $m = 2.2 \text{ kg}$; $\mu_\text{K} = 0.41$; $\vec{F}_\text{a} = 18 \text{ N [E]}$

Required: $\vec{a}$

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: For the *y*-components of the force:

$$\begin{aligned} \Sigma\vec{F}_y &= 0 \text{ N} \\ \vec{F}_\text{N} - mg &= 0 \text{ N} \\ \vec{F}_\text{N} &= mg \end{aligned}$$

For the *x*-components of the force:

$$\begin{aligned} \Sigma\vec{F}_x &= m\vec{a} \\ \vec{F}_\text{a} - \vec{F}_\text{K} &= m\vec{a} \\ \vec{F}_\text{a} - \mu_\text{K}\vec{F}_\text{N} &= m\vec{a} \\ \vec{F}_\text{a} - \mu_\text{K}mg &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_\text{a} - \mu_\text{K}mg}{m} \\ &= \frac{18 \text{ N} - 0.41(2.2 \cancel{\text{ kg}})(9.8 \text{ m/s}^2)}{2.2 \cancel{\text{ kg}}} \\ \vec{a} &= 4.2 \text{ m/s}^2 \end{aligned}$$

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

64. Given: $\vec{a} = 6.6 \text{ m/s}^2$ [backward]

Required: μ_K

Analysis: $\Sigma\vec{F} = m\vec{a}$; $\vec{F}_K = \mu_K \vec{F}_N$. Choose east and up as positive.

Solution: y-component of net force:

$$\begin{aligned} \Sigma\vec{F}_y &= 0 \text{ N} \\ \vec{F}_N - mg &= 0 \text{ N} \\ \vec{F}_N &= mg \end{aligned}$$

x-component of net force:

$$\begin{aligned} \Sigma\vec{F}_x &= m\vec{a} \\ -\vec{F}_K &= m\vec{a} \\ -\mu_K mg &= m\vec{a} \\ \mu_K &= -\frac{\vec{a}}{g} \\ &= -\left(\frac{-6.6 \ \cancel{\text{m/s}^2}}{9.8 \ \cancel{\text{m/s}^2}}\right) \\ \mu_K &= 0.67 \end{aligned}$$

Statement: The coefficient of kinetic friction between the object and the plane is 0.67.

65. Given: $m_1 = 2.2 \text{ kg}$ (Box 1); $m_2 = 3.8 \text{ kg}$ (Box 2); $\mu_S = 0.25$; $\mu_K = 0.32$

Required: $\vec{F}_a$

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: For the y-components of the force (Box 1):

$$\begin{aligned} \Sigma\vec{F}_y &= 0 \text{ N} \\ \vec{F}_{N12} - m_1 g &= 0 \text{ N} \\ \vec{F}_{N12} &= m_1 g \end{aligned}$$

For the x-components of the force (Box 1):

$$\begin{aligned} \Sigma\vec{F}_x &= m_1\vec{a} \\ \vec{F}_S &= m_1\vec{a} \\ \mu_S m_1 g &= m_1\vec{a} \\ \vec{a} &= \mu_S g \end{aligned}$$

For the y-components of the force (Box 2):

$$\begin{aligned} \Sigma\vec{F}_y &= 0 \text{ N} \\ \vec{F}_{N2F} - \vec{F}_{N12} - m_2 g &= 0 \text{ N} \\ \vec{F}_{N2F} &= m_2 g + \vec{F}_{N12} \\ \vec{F}_{N2F} &= (m_1 + m_2)g \end{aligned}$$

For the x-components of the force (Box 2):

$$\begin{aligned}
\Sigma\vec{F}_x &= m_2\vec{a} \\
\vec{F}_a - \vec{F}_K - \vec{F}_S &= m_2\vec{a} \\
\vec{F}_a &= \vec{F}_K + \vec{F}_S + m_2\mu_S g \\
&= \mu_K(m_1+m_2)g + \mu_S m_1 g + m_2\mu_S g \\
&= (\mu_K+\mu_S)(m_1+m_2)g \\
&= (0.57)(6.0)(9.8\ \text{m/s}^2) \\
\vec{F}_a &= 34\ \text{N}
\end{aligned}$$

Statement: The maximum horizontal force that can be applied to the larger box is 34 N.

Evaluation

66. Action and reaction forces cannot cancel each other, even though they are equal and opposite, because one force acts on one object and the other force acts on the second object. These forces do not cancel because they do not act on the same object. Therefore, the student's statement is not valid.

67. Answers may vary. Sample answer: I could try pulling forward and up on the rope attached to the crate. This reduces the normal force and reduces the upper limit of static friction. I might try altering the surface between the crate and the ground to reduce the coefficient of static friction. By tipping the crate a bit I could slide a plastic tarp partway underneath or toss under some ice cubes. I might also tie the rope around a fence post and back on the crate, and then lean against the middle of the rope to get the crate moving.

68. (a) This setup provides an advantage to climbing the rope because the forces acting on the person are the force of gravity (down) and the two rope tensions (up). The two rope tensions share the person's weight. The person is pulling on the left rope creating its tension. As a result, her pulling force is equal to only part of her weight. If she were climbing the rope directly, she would be pulling against her whole weight.

(b) Given: $m = 59.2$ kg; $\Sigma\vec{F} = 0$ N

Required: $\vec{F}_{T1}$

Analysis: $\Sigma\vec{F}_y = 0$ N

Solution:

$$\begin{aligned}
\Sigma\vec{F}_y &= 0\ \text{N} \\
2\vec{F}_T - mg &= 0\ \text{N} \\
\vec{F}_T &= \frac{mg}{2} \\
&= \frac{(59.2\ \text{kg})(9.8\ \text{m/s}^2)}{2} \\
\vec{F}_T &= 2.9\times10^2\ \text{N}
\end{aligned}$$

Statement: The magnitude of force that the person exerts on the rope is 2.9×10^2 N.

(c) Answers may vary. Sample answer: We assumed that the weight of the swing and the rope are negligible and that the pulley is frictionless.

69. The correct order of steps for solving two-dimensional force problems that require Newton's second law of motion is:
(f) Read the problem before trying to solve it.
(c) Identify the given variables and the required variables.
(e) Identify the object on which the forces act.
(d) Choose a coordinate system, and draw an FBD. Include a label for each force.
(b) Determine the *x*- and *y*-components of each force, and write the necessary equations.
(a) Solve the problem using Newton's second law of motion.
70. The student might say this because, if the cross-country skier had no friction sliding down the small hills, his acceleration and speed would be greater. If there were no friction, the skier would not be able to get up the hill because the skier needs traction between the skis and the snow. Without friction, the force of gravity would keep the skier from going up the hill.
71. (a) Given: coefficient of static friction on dry pavment, $\mu_{S1} = 0.81$;
coefficient of static friction on wet pavment, $\mu_{S2} = 0.58$
Required: acceleration on dry pavement, $\vec{a}_1$; acceleration on wet pavement, $\vec{a}_2$
Analysis: $F_S = \mu_S F_N$; $\Sigma\vec{F} = m\vec{a}$
Solution: For the *y*-components of the force:

$$\begin{aligned}\Sigma\vec{F}_y &= 0 \text{ N}\\ \vec{F}_N - mg &= 0 \text{ N}\\ \vec{F}_N &= mg\end{aligned}$$

For the *x*-components of the force:

$$\begin{aligned}\Sigma\vec{F}_x &= m\vec{a}\\ \vec{F}_S &= m\vec{a}\\ \mu_S\vec{F}_N &= m\vec{a}\\ \mu_S \cancel{m}g &= \cancel{m}\vec{a}\\ \vec{a} &= \mu_S g\end{aligned}$$

$$\begin{aligned}\vec{a}_1 &= \mu_{S1}g\\ &= 0.81(9.8 \text{ m/s}^2)\\ &= 7.938 \text{ m/s}^2 \text{ (two extra digits carried)}\\ \vec{a}_1 &= 7.9 \text{ m/s}^2\end{aligned}$$

$$\begin{aligned}\vec{a}_2 &= \mu_{S2}g\\ &= 0.58(9.8 \text{ m/s}^2)\\ &= 5.684 \text{ m/s}^2 \text{ (two extra digits carried)}\\ \vec{a}_2 &= 5.7 \text{ m/s}^2\end{aligned}$$

Statement: The maximum acceleration on dry pavement is 7.9 m/s^2 and 5.7 m/s^2 on wet pavement.
(b) Given: $\vec{a}_1 = 7.398 \text{ m/s}^2$; $\vec{a}_2 = 5.684 \text{ m/s}^2$; $\Delta d = 100 \text{ m}$; $v_i = 0 \text{ m/s}$
Required: time running 100 m on dry pavement, Δt_1; time running 100 m on wet pavement, Δt_2

Analysis: $\Delta d = v_i \Delta t + \frac{1}{2} a(\Delta t)^2$

Solution: $\Delta d = v_i \Delta t_1 + \frac{1}{2} \vec{a}_1 (\Delta t_1)^2$ $\qquad$ $\Delta d = v_i \Delta t_2 + \frac{1}{2} \vec{a}_2 (\Delta t_2)^2$

$$\Delta d = v_i \Delta t_1 + \frac{1}{2} \vec{a}_1 (\Delta t_1)^2 \qquad \Delta d = v_i \Delta t_2 + \frac{1}{2} \vec{a}_2 (\Delta t_2)^2$$

$$\Delta t_1 = \sqrt{\frac{2\Delta d}{\vec{a}_1}} \qquad \Delta t_2 = \sqrt{\frac{2\Delta d}{\vec{a}_2}}$$

$$= \sqrt{\frac{200\ \cancel{\text{m}}}{7.938\ \cancel{\text{m}}/\text{s}^2}} \qquad = \sqrt{\frac{200\ \cancel{\text{m}}}{5.684\ \cancel{\text{m}}/\text{s}^2}}$$

$$\Delta t_1 = 5.0\ \text{s} \qquad \Delta t_2 = 5.9\ \text{s}$$

Statement: The length of time you could run 100 m with sustained acceleration when the pavement is dry is 5.0 s, and when wet is 5.9 s. Both of these times are unreasonably short, given that the Olympic record for 100 m is between 9 s and 10 s.

72. Given: $m = 52$ kg; $\vec{F}_1 = 3.4 \times 10^2$ N [forward 25° up];
$\vec{F}_2 = 1.7 \times 10^2$ N [forward 25° down]; $\mu_K = 0.52$

Required: $\vec{a}$

Analysis: $\Sigma \vec{F}_y = 0$ N; $\Sigma \vec{F}_x = m\vec{a}$. Choose forward and up as positive.

Solution: For the y-components of the force:

$$\Sigma \vec{F}_y = 0\ \text{N}$$

$$\vec{F}_{1y} + \vec{F}_{2y} + \vec{F}_N - mg = 0\ \text{N}$$

$$\vec{F}_N = (52\ \text{kg})(9.8\ \text{m/s}^2) - (340\ \text{N})\sin 25° - (-170\ \text{N})\sin 25°$$

$$\vec{F}_N = 437.8\ \text{N (two extra digits carried)}$$

For the x-components of the force:

$$\Sigma \vec{F}_x = m\vec{a}$$

$$\vec{F}_{1x} + \vec{F}_{2x} - \vec{F}_K = m\vec{a}$$

$$\vec{a} = \frac{(340\ \text{N})\cos 25° + (170\ \text{N})\cos 25° - (0.52)(437.8\ \text{N})}{52\ \text{kg}}$$

$$\vec{a} = 4.5\ \text{m/s}^2$$

Statement: The crate accelerates at 4.5 m/s^2.

73. Given: $\mu_{dry} = 0.85$; $\mu_{wet} = 0.45$

Required: $\Delta d_{dry} = \frac{v_f^2 - v_i^2}{2\vec{a}_{dry}}$;

Analysis: $\Sigma \vec{F} = m\vec{a}$; $\vec{F}_K = \mu_K \vec{F}_N$; $\Delta d = \frac{v_f^2 - v_i^2}{2\vec{a}}$; $\Delta d_{wet} = \frac{v_f^2 - v_i^2}{2\vec{a}_{wet}}$. Choose up and forward as positive.

Solution: For the *y*-components of the force:

$$\Sigma\vec{F}_y = 0\text{ N}$$
$$\vec{F}_\text{N} - mg = 0\text{ N}$$
$$\vec{F}_\text{N} = mg$$

For the *x*-components of the force:

$$\Sigma\vec{F}_x = m\vec{a}$$
$$-\vec{F}_\text{K} = m\vec{a}$$
$$-\mu_\text{K}\vec{F}_\text{N} = m\vec{a}$$
$$-\mu_\text{K}\cancel{m}g = \cancel{m}\vec{a}$$
$$\vec{a} = -\mu_\text{K}g$$

Stopping distance for dry concrete:

$$\Delta d_\text{dry} = \frac{v_\text{f}^2 - v_\text{i}^2}{2\vec{a}_\text{dry}}$$
$$\Delta d_\text{dry} = \frac{-v_\text{i}^2}{2(-\mu_\text{dry}g)}$$
$$\Delta d_\text{dry} = \frac{v_\text{i}^2}{2\mu_\text{dry}g}$$

Stopping distance for dry concrete:

$$\Delta d_\text{wet} = \frac{v_\text{f}^2 - v_\text{i}^2}{2\vec{a}_\text{wet}}$$
$$\Delta d_\text{wet} = \frac{-v_\text{i}^2}{2(-\mu_\text{wet}g)}$$
$$\Delta d_\text{wet} = \frac{v_\text{i}^2}{2\mu_\text{wet}g}$$

The required comparison of distances is:

$$\frac{\Delta d_\text{wet}}{\Delta d_\text{dry}} = \frac{\cancel{v_\text{i}^2}}{\cancel{2}\mu_\text{wet}\cancel{g}} \times \frac{\cancel{2}\mu_\text{dry}\cancel{g}}{\cancel{v_\text{i}^2}}$$
$$= \frac{\mu_\text{dry}}{\mu_\text{wet}}$$
$$= \frac{0.85}{0.45}$$
$$\frac{\Delta d_\text{wet}}{\Delta d_\text{dry}} = 1.9$$

Statement: The car would skid about 90 % farther on wet concrete than on dry concrete, assuming the same initial speed in both cases. This calculation suggests that in wet conditions it would be wise to drive more slowly and leave more space between you and other cars to accommodate the much longer skid distance in wet conditions.

74. (a) Given: $\vec{F}_{\text{air}} = 0\ \text{N}$; $m_1 = 59\ \text{kg}$; $m_2 = 73\ \text{kg}$; $\theta = 23°$; $\mu_{\text{K}} = 0.10$

Required: a_1; a_2

Analysis: $\vec{a} = g\sin\theta - \mu_{\text{K}} g\cos\theta - \dfrac{\vec{F}_{\text{air}}}{m}$

Solution:
$$\begin{aligned}\vec{a} &= g\sin\theta - \mu_{\text{K}} g\cos\theta \\ &= (9.8\ \text{m/s}^2)\sin 23° - 0.10(9.8\ \text{m/s}^2)\cos 23° \\ &= 2.927\ \text{m/s}^2\ \text{(two extra digits carried)} \\ \vec{a} &= 2.9\ \text{m/s}^2\end{aligned}$$

Statement: With no air resistance, both skiers would have an acceleration of 2.9 m/s^2 down the slope.

(b) Given: $F_{\text{air}} = 82\ \text{N}$; $\vec{a} = 2.927\ \text{m/s}^2$

Required: $\vec{a}_1$; $\vec{a}_2$

Analysis: $\vec{a} = g\sin\theta - \mu_{\text{K}} g\cos\theta - \dfrac{\vec{F}_{\text{air}}}{m}$

Solution:
$$\begin{aligned}\vec{a}_1 &= g\sin\theta - \mu_{\text{K}} g\cos\theta - \frac{\vec{F}_{\text{air}}}{m_1} \\ &= 2.927\ \text{m/s}^2 - \frac{82\ \text{N}}{59\ \text{kg}} \\ \vec{a}_1 &= 1.5\ \text{m/s}^2\end{aligned}$$
$$\begin{aligned}\vec{a}_2 &= g\sin\theta - \mu_{\text{K}} g\cos\theta - \frac{\vec{F}_{\text{air}}}{m_2} \\ &= 2.927\ \text{m/s}^2 - \frac{82\ \text{N}}{73\ \text{kg}} \\ \vec{a}_2 &= 1.8\ \text{m/s}^2\end{aligned}$$

Statement: Assuming the same air resistance acts on both skiers, skier 1 accelerates at 1.5 m/s^2 while skier 2 accelerates at 1.8 m/s^2. There is a smaller effect from air resistance on the heavier skier compared to the lighter skier; with the given data, the increase in acceleration is 0.3 m/s^2 or 20 %.

(c) There is a difference of 0.3 m/s^2 between the skiers in part (b). This difference represents a 20 % increase in acceleration for the heavier skier. This difference could affect the race because the heavier skier would have the faster time, and therefore, win the race.

Reflect on Your Learning

75. Answers may vary. Sample answer: To explain the common forces I would ask students to describe a situation where they knew that some forces were acting. I would have them brainstorm what forces they thought were in play. Someone could write the suggestions on the board and with the help of the other students organize them into categories. To explain FBDs, I would work from a system diagram for one of the student examples to an FBD. I would make sure to do an example with action–reaction forces and two bodies. This would address the issue of which body to put a given force on.

76. Answers may vary. Sample answer: I was surprised to realize that the physics way of analyzing forces and motion applies everywhere in my life. This approach is especially useful in looking at sports, such as how to use friction to jump effectively, and how to lean when skiing.
77. Answers will vary. Sample answer: In this chapter I learned about the difference between static and kinetic friction. I suppose I was aware of the two kinds of friction but never really made a distinction. It was interesting to realize that static friction can work in a forward direction to make it possible to walk or drive.
78. Answers may vary. Sample answer: I have noticed that it is often easier to pull a heavy box than to push it. Now I realize that when I pull my applied force has an upward component while when I push my applied force has a downward component. This affects the normal force and the friction I am working against. A question for my fellow students: Give an example of a situation where the normal force is larger than the weight of the object.
79. Answers may vary. Sample answer: I was most surprised to see how the force of gravity works on an inclined plane.
80. Answers may vary. Sample answer: My car battery is often dead and I am always getting a push or a tow. I really can see how action–reaction force pairs work because of this experience.

Research
81. Answers may vary. Sample answer: Students' answers should mention the following points. Students should describe biomechanics as an application of physics and mechanics principles to biological systems, including the motion of athletes. Students should discuss that a force platform is a device for measuring the forces exerted by a body as it moves, and how this information can help athletes learn to move efficiently.
82. Answers may vary. A student presentation may include a short history of seat belts from 1959, when Volvo first made them standard equipment, to the present. It should also explain some of the features of modern seatbelts. One is the locking retractor, that is, a spring-loaded reel equipped with an inertial locking mechanism that stops the belt from extending off the reel during sudden slow downs. Another is the pretensioner that preemptively tightens a seatbelt to prevent an occupant from jerking forward in a crash. Web clamps clamp the webbing in the event of an accident and limit the distance the webbing can spool out. Automatic seatbelts automatically move into position around an occupant once the car door is closed or the engine is started. Students can also describe current developments such as inflatable seatbelts and improved safety in the professional car racing sector. Explanations should reference the concepts of force and friction and also the principles of mechanics.
83. Answers may vary. A summary of research should include examples of how belts and ropes are used in climbing by professional arborists as well as recreational climbers in rock climbing or mountaineering. There should be a discussion of how friction keeps knots tied and hitches secure as well as how friction can be a problem. Sometimes friction can be too great and interfere with the climbing operation. A number of devices have been invented to reduce and/or control friction. These include general devices such as carabiners, and pulleys and specific devices such as the Cambrium Saver, the Friction Saver, the Rope Guide, and Buck Blocks that are used by arborists. The summary may

also describe some of the factors that affect friction in the physical world such as softness, roughness, temperature, and moisture.

84. Student's answers may vary. Students' answers should include an explanation of how the principles of motion are applied in archery. Factors to consider should include the bow, the arrow, and atmospheric conditions. Factors affecting the arrow are the initial angle the arrow is aimed, its initial velocity, its weight, its length, the length of the arrow's feathers, as well as the height of the arrow's feathers. Bow factors can include draw length and draw force. Atmospheric factors can include gravity, friction, and wind. Students should use Newton's laws of motion in their explanations.

Chapter 2 Self-Quiz, page 99

1. (d)
2. (a)
3. (b)
4. (b)
5. (c)
6. (c)
7. (b)
8. (d)
9. False. When you jump up in the air, the net force on you is equal to the force of *gravity*.
10. True
11. False. According to Newton's third law of motion, the forces of action and reaction always act on *different* bodies and *are equal in magnitude and opposite in direction* to each other.
12. False. In a tug-of war between two athletes, each pulls on the rope with a force of 300 N. The tension in the rope is *300 N*.
13. True
14. False. On a rainy day, it can be dangerous to drive a car at high speed, because the rain on the road surface *decreases* the coefficients of friction.
15. False. Downhill skiers go into a crouching position to *decrease* air resistance and *increase* speed.