Chapter 2

FORCE

Conceptual Questions

1. In an automobile accident the force due to the collision changes the motion of the car, but the driver and passengers continue to move in accordance with Newton's first law. Seat belts supply the force necessary to change their motion and slow them down. Without seat belts people would collide with the steering wheel or windshield, for example, and stand a greater risk of injury.

2. When the person strikes the rug with the carpet beater, the rug begins to move forward. The carpet frame supplies the force to overcome the inertia of the rug and hold it in place, while the inertia of the dust causes it to continue moving forward. Similarly, when someone throws a baseball the inertia of the ball causes it to continue moving after it has left the person's hand.

3. There are a number of forces still acting on you, such as the normal force from the ground pushing up and the force of gravity pulling down. The forces largely cancel each other though, so the net force acting on you is essentially zero.

4. When the dog shakes, his wet fur changes velocity back and forth. The water will only remain on the fur if it has the same velocity as the fur, so there must be a sufficiently large force holding it on as the dog shakes. When the force is not sufficient, drops of water lose contact with the fur and experience no more force from the dog's motion. From the principle of inertia (Newton's first law) these drops resist changes in velocity, so they fly off the dog's body with whatever velocity they had when they lost contact. The drops in the air will then fall to the ground due to the force of gravity. As the dog continues shaking himself, more drops are shaken loose.

5. When the handle hits the board and stops abruptly, Newton's first law says that the steel head will continue to move for a short distance, resisting changes in velocity, until the force of friction between the head and the handle has brought it to rest. It will have then moved down some to where the handle is a little wider, resulting in a tightening of the head onto the handle.

6. The road pushes on the tires causing the car to move forward. The engine facilitates this process by rotating the wheels so they push backwards on the road. In accordance with Newton's third law the road exerts an equal and opposite external force on the tires.

7. Because of the principle of inertia, the cars continue moving until a sufficient force has caused them to stop. The contact force between the cars at the moment of collision starts to slow them down. Before this force has stopped the cars completely they will have moved a small distance, crumpling the front ends. The rear end of the car continues to move while the front end is being crumpled, until it too comes to rest.

8. **(a)** Yes, since the direction matters. See Fig. 2.2c.

(b) No. The largest possible magnitude occurs when the two vectors point in the same direction. Then the magnitude of the sum equals the sum of the magnitudes.

9. **(a)** The reading of the scale is the magnitude of the normal force pushing up on you. This equals your weight as long as the normal force and the force of gravity are the only forces acting on you, and you are at rest or moving with a constant velocity.

(b) If you were standing on the scale in a swimming pool for example, there would be a buoyant force from the water pushing up on you, and the scale would read a smaller apparent weight. Also, the scale would not read your weight if you were accelerating—for example standing on the scale in an elevator as it was moving upward with increasing speed.

10. **(a)** False. Moving at constant speed, the engine must be pulling with a force equal to the force of friction, which under ordinary conditions is much less than the train's weight.

(b) False. By Newton's third law, the engine's pull on the first car and that car's pull on the engine must always be equal in magnitude and opposite in direction.

(c) False. Its inertia would cause it to keep coasting at a constant speed. The force of friction would cause the train to slow down and eventually stop.

11. The weight of a person is the force of gravitational attraction on that person due to the Earth. This force is inversely proportional to the square of the distance between the person and the center of the Earth.

(a) The rotation of the Earth causes a flattening of the planet such that the radius along the equator is greater than the radius from pole to pole. The man would therefore weigh more at the North Pole where his distance to the center of the Earth is less.

(b) The man would weigh more at the base of the mountain because, once again, this location is closer to the center of the Earth, thus increasing the force of gravitational attraction.

12. A vector is a quantity that has both a magnitude and a direction associated with it. Velocity and displacement are both examples of vector quantities. A scalar is a quantity that is only defined by a magnitude—it has no direction associated with it. Scalar quantities include speed and distance traveled.

13. The key is that the equal and opposite forces of Newton's third law are acting on two different objects—one on the wagon and the other on you. The wagon can therefore experience a non-zero net force, which causes it to accelerate forward.

14. No single component of a vector can ever be greater than the magnitude of the vector. This is equivalent to the statement that each side of a right triangle must be shorter than its hypotenuse—a statement that can be verified using the Pythagorean Theorem.

15. The top string would be the first to break, since the tension it experiences is larger by an amount equal to the weight of the ball it is holding up.

16. The forces are equal in magnitude, in accordance with Newton's third law. The resulting changes in velocity will not be equal though, because the masses are different.

17. Newton's third law tells us that if the person on the raft walks away from the pier, the raft will in turn move toward the pier. Thus, after walking the length of the raft, it should be possible for the person with the hook on the pier to grab the raft and reel it in. Without the person on the pier to hold the raft, this technique would be of no use, as the raft would move back away from the pier on the return walk.

18. No; to be equal they must also have the same direction. If the magnitudes are different, they cannot be equal.

19. The primary benefit of graphical vector addition is its use in providing a visual understanding of the problem—a feature that is often obscured in algebraic vector addition. Despite this benefit, adding vectors graphically is a cumbersome and imprecise process whereas the algebraic method is relatively easy to perform and provides much greater accuracy. These benefits make the algebraic method the favored choice in most situations.

20. A simple pulley allows one to change the direction of an applied force. For example one may lift a heavy box up by attaching it to a rope with a pulley. One then pulls down on the rope to produce an upward force on the box. A more complex system of pulleys can reduce the force that must be applied in order to lift the object. An inclined plane can also be used to reduce the force necessary to move an object up. In pushing a heavy box up an inclined plane, the force required is less than the box's weight.

21. Yes, as long as the y-axis is perpendicular to the chosen x-axis. This will often simplify a problem.

22. The tension is the same everywhere along the line.

23. No; the concept of contact force is valid only for the macroscopic scale. The idea of contact breaks down at the atomic scale, since there is no way to define contact between atoms.

Multiple-Choice Questions

1. (b) **2.** (b) **3.** (a) **4.** (b) **5.** (d) **6.** (b) **7.** (c) **8.** (c) **9.** (d) **10.** (b) **11.** (c) **12.** (b) **13.** (a) **14.** (e) **15.** (a) **16.** (c) **17.** (b) **18.** (d)

Problems

1. Strategy Determine the forces *not* acting on the scale.

Solution The scale is in contact with the floor, so a contact force due to the floor is exerted on the scale. The scale is in contact with the person's feet, so a contact force due to the person's feet is exerted on the scale. The scale is in the proximity of a very large mass (Earth), so the weight of the scale is a force exerted on the scale. $\boxed{\text{The weight of the person}}$ is a force exerted on the person due to the very large mass, so it is not a force exerted on the scale.

2. Strategy Distinguish between the vector and scalar quantities.

Solution Volume, speed, length, and time are directionless, therefore, they are scalar quantities. $\boxed{\text{Force}}$ has both direction and magnitude, therefore, it is a vector quantity.

3. Strategy Distinguish between the vector and scalar quantities.

Solution Temperature, test score, stock value, humidity, and mass are directionless quantities, therefore, they are scalar quantities. $\boxed{\text{Velocity}}$ has both direction and magnitude; therefore, it is a vector quantity (and not a scalar).

4. Strategy There are 0.2248 pounds per newton.

Solution Find the weight of the sack of flour in pounds.

$$19.8\ \text{N} \times \frac{0.2248\ \text{lb}}{1\ \text{N}} = \boxed{4.45\ \text{lb}}$$

5. Strategy There are 0.2248 pounds per newton.

Solution Find the weight of the astronaut in newtons.

$$175\ \text{lb} \times \frac{1\ \text{N}}{0.2248\ \text{lb}} = \boxed{778\ \text{N}}$$

6. Strategy Apply the Pythagorean theorem to the components of each vector.

Solution Find the magnitude of each vector.

$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{4^2 + 4^2} = \sqrt{16+16} = \sqrt{32}$$

$$B = \sqrt{B_x^2 + B_y^2} = \sqrt{(-1)^2 + 3^2} = \sqrt{1+9} = \sqrt{10}$$

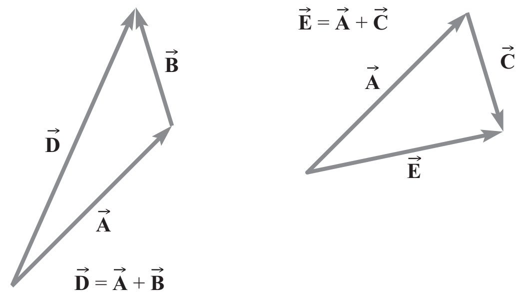
$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{1^2 + (-3)^2} = \sqrt{1+9} = \sqrt{10}$$

In order of increasing magnitude, we have $\boxed{B = C, A}$.

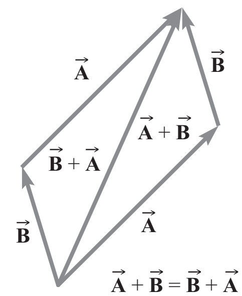
7. **Strategy** Find graphically the vectors $\vec{\mathbf{D}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$ and $\vec{\mathbf{E}} = \vec{\mathbf{A}} + \vec{\mathbf{C}}$. Then, show graphically that $\vec{\mathbf{A}} + \vec{\mathbf{B}} = \vec{\mathbf{B}} + \vec{\mathbf{A}}$.

   Solution Use graph paper, ruler, and protractor to find the magnitude and direction of the vector sum of the two forces in each case.

(a)

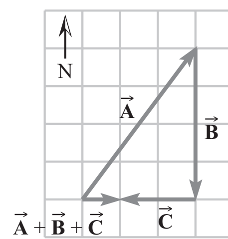


(b)



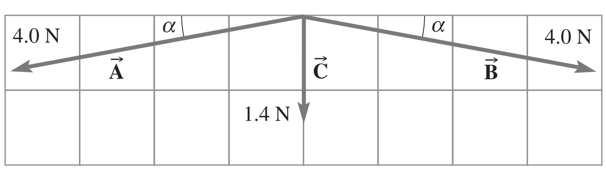
8. **Strategy** Graph the vectors and their sum. Use the scale of the graph to find the magnitude of the vector sum.

   Solution The length of the vector sum is equal to one side of a grid square, so the magnitude is 2 N. The vector points east, so the vector sum of the forces is 2 N to the east.



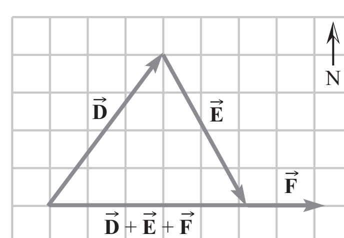
9. **Strategy** Use the fact that $|\vec{\mathbf{A}}| = |\vec{\mathbf{B}}|$ and symmetry to determine the direction of $\vec{\mathbf{C}}$; then sketch $\vec{\mathbf{C}}$.

   Solution By symmetry, we find that $\vec{\mathbf{C}}$ points downward; the horizontal components cancel when $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ are added. The downward components of each vector have the same magnitude, about 0.7 N. So, the magnitude of $\vec{\mathbf{C}}$ is about 1.4 N. The sketch is shown:



10. **Strategy** Graph the vectors and their sum. Use the scale of the graph to find the magnitude of the vector sum.

    Solution The length of the vector sum is approximately equal to seven sides of a grid square, so the magnitude is 14 N. The vector points east, so the vector sum of the forces is 14 N to the east. (Note that $\vec{\mathbf{F}}$ and the vector sum overlap.)



11. Strategy Apply the Pythagorean theorem to the components of each vector.

Solution Find the magnitude of each vector.

$$D = \sqrt{D_x^2 + D_y^2} = \sqrt{3^2 + 4^2} = \sqrt{9+16} = \sqrt{25} \text{ N} = 5 \text{ N}$$

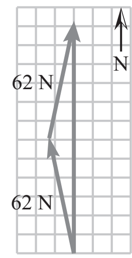
$$E = \sqrt{E_x^2 + E_y^2} = \sqrt{2^2 + (-4)^2} = \sqrt{4+16} = \sqrt{20} \text{ N} = 2\sqrt{5} \text{ N} \approx 4.5 \text{ N}$$

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{2^2 + 0^2} = \sqrt{4} \text{ N} = 2 \text{ N}$$

In order of increasing magnitude, we have $\boxed{F, E, D}$.

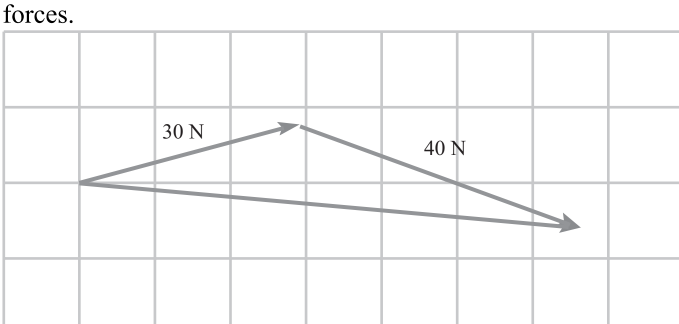
12. Strategy Graph the vectors and their sum. Use the scale of the graph to find the magnitude of the vector sum.

Solution Use graph paper, ruler, and protractor to find the magnitude and direction of the vector sum of the two forces. The vector sum points due north. Each side of a grid square represents 10 N, so the magnitude of the net force on the sledge is about $\boxed{120 \text{ N}}$.



13. Strategy Represent 10 N as a length of 1 cm. Then, 30 N is represented by 3 cm and 40 N is represented by 4 cm.

Solution Use graph paper, ruler, and protractor to find the magnitude and direction of the vector sum of the two forces.



Using the ruler, we find that the magnitude of the vector sum of the forces is about $\boxed{70 \text{ N}}$. Using the protractor, we find that the direction of the vector sum of the forces is $\boxed{\text{about } 5° \text{ below the horizontal}}$.

14. Strategy Find the *x*-coordinate of the terminal point starting from the initial point.

Solution Find the *x*-coordinate of each vector.

$A_x = 3; B_x = 0; C_x = -2$

In order of increasing *x*-coordinate, we have $\boxed{C_x, B_x, A_x}$.

15. Strategy Find the *y*-coordinate of the terminal point starting from the initial point.

Solution Find the *y*-coordinate of each vector.

$D_y = 4; E_y = -4; F_y = 0$

In order of increasing *y*-coordinate, we have $\boxed{E_y, F_y, D_y}$.

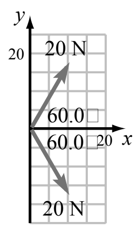
16. Strategy Add the corresponding x-components of each vector sum.

Solution Find the x-components.
$A_x + B_x = 4 + (-1) = 3; B_x + C_x = -1 + 1 = 0; A_x + C_x = 4 + 1 = 5$

In order of increasing x-component, we have $\boxed{B_x + C_x, A_x + B_x, A_x + C_x}$.

17. Strategy Use graph paper to draw a diagram.

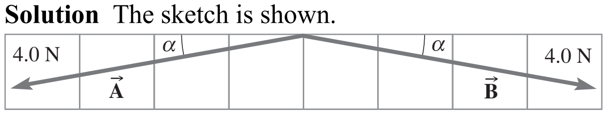
Solution Find the vector sum of the vectors.



Because of symmetry, the y-components of the vectors cancel. The x-components look to be about 10 N, so the vector sum is $10\text{ N} + 10\text{ N} = 20\text{ N}$, or $\boxed{\text{20 N in the positive } x\text{-direction}}$.

18. Strategy Sketch the situation and use the component method to find the magnitude of $\vec{\mathbf{C}}$.

Solution The sketch is shown.



Add the components of the vectors.

$C_x = A_x + B_x = -(4.0\text{ N})\cos 10° + (4.0\text{ N})\cos 10° = 0$

$C_y = A_y + B_y = -(4.0\text{ N})\sin 10° - (4.0\text{ N})\sin 10° = -(8.0\text{ N})\sin 10° = -1.4\text{ N}$

The magnitude of $\vec{\mathbf{C}}$ is $\boxed{1.4\text{ N}}$.

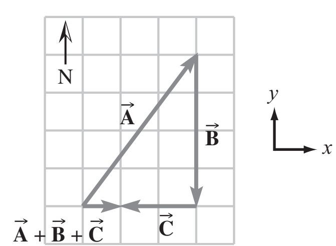
19. Strategy Graph the vectors and their sum. Use the graph and the grid to estimate the components of the vectors. Then use the component method to find the vector sum.

Solution Find the vector sum.

x-comp: $A_x + B_x + C_x = 3(2\text{ N}) + 0(2\text{ N}) - 2(2\text{ N}) = 2\text{ N}$

y-comp: $A_y + B_y + C_y = 4(2\text{ N}) - 4(2\text{ N}) + 0(2\text{ N}) = 0$

The vector sum of the forces is 2 N in the positive x-direction or $\boxed{\text{2 N to the east}}$.



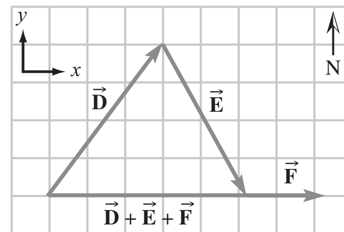
20. **Strategy** Graph the vectors and their sum. Use the graph and the grid to estimate the components of the vectors. Then use the component method to find the vector sum.

Solution Find the vector sum.

x-comp: $D_x + E_x + F_x = 3(2\text{ N}) + 2(2\text{ N}) + 2(2\text{ N}) = 14\text{ N}$

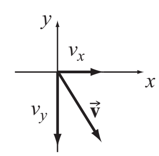
y-comp: $D_y + E_y + F_y = 4(2\text{ N}) - 4(2\text{ N}) + 0(2\text{ N}) = 0$

The vector sum of the forces is 14 N in the positive x-direction or $\boxed{\text{14 N to the east}}$.



21. **Strategy** The components of $\vec{\mathbf{v}}$ are given. Since the x-component is positive and the y-component is negative, the vector lies in the fourth quadrant. Give the angle with respect to the axes.

Solution Find the magnitude and direction of $\vec{\mathbf{v}}$.



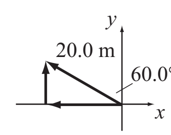
(a) $v = \sqrt{{v_x}^2 + {v_y}^2} = \sqrt{(16.4\text{ m/s})^2 + (-26.3\text{ m/s})^2} = \boxed{31.0\text{ m/s}}$

(b) $\theta = \tan^{-1}\dfrac{-26.3}{16.4} = \boxed{58.1^\circ \text{ with the } +x\text{-axis and } 31.9^\circ \text{ with the } -y\text{-axis}}$

22. **Strategy** The vector makes an angle of 60.0° counterclockwise from the y-axis. So, the angle from the positive x-axis is 90.0° + 60.0° = 150.0°.

Solution Find the components of the vector.

$x\text{-comp} = (20.0\text{ m})\cos(150.0^\circ) = \boxed{-17.3\text{ m}}$ and $y\text{-comp} = (20.0\text{ m})\sin(150.0^\circ) = \boxed{10.0\text{ m}}$.

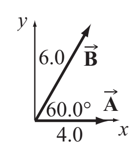


23. **Strategy** Let $\vec{\mathbf{A}}$ be directed along the $+x$-axis and let $\vec{\mathbf{B}}$ be 60.0° CCW from $\vec{\mathbf{A}}$.

Solution Find the magnitude of $\vec{\mathbf{A}} + \vec{\mathbf{B}}$.

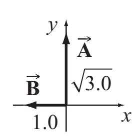
$(A+B)_x = A_x + B_x = 4.0 + 6.0\cos 60.0^\circ = 7.0$ and $(A+B)_y = A_y + B_y = 0 + 6.0\sin 60.0^\circ = 5.2,$ so

$\left|\vec{\mathbf{A}} + \vec{\mathbf{B}}\right| = \sqrt{7.0^2 + 5.2^2} = \boxed{8.7\text{ units}}$.



24. **Strategy** Since each vector is directed along a different axis, each component of the vector sum is equal to the magnitude of the vector that lies along that component's axis.

Solution Find the magnitude of $\vec{\mathbf{A}} + \vec{\mathbf{B}}$.



$\left|\vec{\mathbf{A}} + \vec{\mathbf{B}}\right| = \sqrt{[(A+B)_x]^2 + [(A+B)_y]^2} = \sqrt{(-1.0)^2 + (\sqrt{3.0})^2} = 2.0\text{ units}$

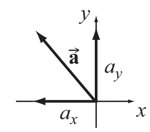
Find the direction.

$\theta = \tan^{-1}\dfrac{\sqrt{3.0}}{-1.0} = 30^\circ$ CCW from the $+y$-axis, so

$\vec{\mathbf{A}} + \vec{\mathbf{B}} = \boxed{2.0\text{ units at } 30^\circ \text{ CCW from the } +y\text{-axis}}$.

25. Strategy The components of $\vec{\mathbf{a}}$ are given. Since the x-component is negative and the y-component is positive, the vector lies in the second quadrant. Give the angle with respect to the axis to which it lies closest.

Solution Find the magnitude and direction of $\vec{\mathbf{a}}$.



(a) $a=\sqrt{a_x{}^2+a_y{}^2}=\sqrt{(-3.0\ \text{m/s}^2)^2+(4.0\ \text{m/s}^2)^2}=\boxed{5.0\ \text{m/s}^2}$

(b) $\theta=\tan^{-1}\dfrac{4.0}{-3.0}=\boxed{37^\circ\text{ CCW from the }+y\text{-axis}}$

26. Strategy Determine the angle each vector makes with the positive x-axis.

Solution Find the components of each vector.

Vector $\vec{\mathbf{A}}$:

$A_x=(7.0\text{ m})\cos 20.0^\circ=\boxed{6.6\text{ m}}$

$A_y=(7.0\text{ m})\sin 20.0^\circ=\boxed{2.4\text{ m}}$

Vector $\vec{\mathbf{B}}$:

$B_x=(7.0\text{ N})\cos(-20.0^\circ)=\boxed{6.6\text{ N}}$

$B_y=(7.0\text{ N})\sin(-20.0^\circ)=\boxed{-2.4\text{ N}}$

Vector $\vec{\mathbf{C}}$:

$C_x=(7.0\text{ m})\cos 110.0^\circ=\boxed{-2.4\text{ m}}$

$C_y=(7.0\text{ m})\sin 110.0^\circ=\boxed{6.6\text{ m}}$

Vector $\vec{\mathbf{D}}$:

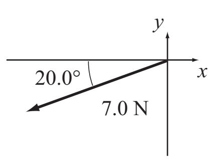
$D_x=(7.0\text{ N})\cos(-110.0^\circ)=\boxed{-2.4\text{ N}}$

$D_y=(7.0\text{ N})\sin(-110.0^\circ)=\boxed{-6.6\text{ N}}$

27. Strategy and Solution Multiplying a vector by a scalar is equivalent to multiplying the vector's components by that scalar value. Multiplying a vector by a positive scalar—other than 1—changes the magnitude of the vector and its components but not the direction. Therefore, doubling the magnitude of the vector doubles both components, without changing their signs.

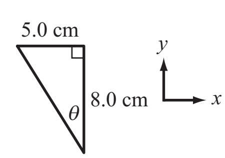
28. Strategy Reversing the sign of the x-component results in both x- and y-components being negative. The resulting vector lies in the third quadrant, 20.0° below the negative x-axis.

Solution The sketch is shown.



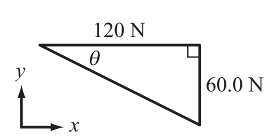
29. Strategy Use the Pythagorean theorem to find the magnitude of each vector. Sketch a right triangle to find the direction angle. Give the angle with respect to the axis to which it lies closest.

Solution Find the magnitude and direction of each vector.



(a) $r=\sqrt{(-5.0\text{ cm})^2+(8.0\text{ cm})^2}=\boxed{9.4\text{ cm}}$ and

$\theta=\tan^{-1}\dfrac{5.0}{8.0}=\boxed{32^\circ\text{ CCW from the }+y\text{-axis}}$.

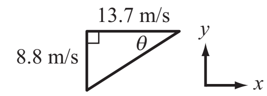


(b) $F=\sqrt{(120\text{ N})^2+(-60.0\text{ N})^2}=\boxed{130\text{ N}}$ and

$\theta=\tan^{-1}\dfrac{60.0}{120}=\boxed{27^\circ\text{ CW from the }+x\text{-axis}}$.

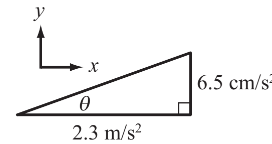
(c) $v=\sqrt{(-13.7\text{ m/s})^2+(-8.8\text{ m/s})^2}=\boxed{16.3\text{ m/s}}$ and

$\theta=\tan^{-1}\dfrac{8.8}{13.7}=\boxed{33°\text{ CCW from the }-x\text{-axis}}.$



(d) $a=\sqrt{(2.3\text{ m/s}^2)^2+(6.5\times10^{-2}\text{ m/s}^2)^2}=\boxed{2.3\text{ m/s}^2}$ and

$\theta=\tan^{-1}\dfrac{0.065}{2.3}=\boxed{1.6°\text{ CCW from the }+x\text{-axis}}.$



30. (a) Strategy Since $\vec{\mathbf{b}}$ is directed at an angle of 14° below the positive x-axis, $\theta=-14°$.

Solution Compute the components of $\vec{\mathbf{b}}$.

$b_x=7.1\cos(-14°)=\boxed{6.9}$ and $b_y=7.1\sin(-14°)=\boxed{-1.7}.$

(b) Strategy Use the Pythagorean theorem to find the magnitude of each vector. Give the angle with respect to the axis to which it lies closest.

Solution Find the magnitude and direction of $\vec{\mathbf{c}}$.

$c=\sqrt{c_x{}^2+c_y{}^2}=\sqrt{(-1.8)^2+(-6.7)^2}=\boxed{6.9}$ and $\theta=\tan^{-1}\dfrac{1.8}{6.7}=\boxed{15°\text{ CW from the }-y\text{-axis}}.$

(c) Strategy Add the components of the vectors to find the components of the vector sum. Use the Pythagorean theorem to find the magnitude of each vector. Give the angle with respect to the axis to which it lies closest.

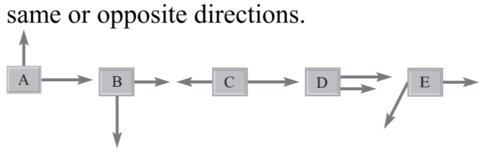
Solution Find the magnitude and direction of $\vec{\mathbf{c}}+\vec{\mathbf{b}}$.

$\left|\vec{\mathbf{c}}+\vec{\mathbf{b}}\right|=\sqrt{(c_x+b_x)^2+(c_y+b_y)^2}=\sqrt{(-1.8+6.9)^2+(-6.7-1.7)^2}=\boxed{9.8}$ and

$\theta=\tan^{-1}\dfrac{5.1}{8.4}=\boxed{31°\text{ CCW from the }-y\text{-axis}}.$

31. Strategy The shorter vectors have magnitude 2000 N and the longer vectors have magnitude 3000 N. Find the components of each vector and add; if necessary, use the Pythagorean theorem or estimate the net force.

Solution Add the vertical and horizontal components of each vector, taking note of whether components have the same or opposite directions.



The net forces on objects C and D are the easiest to determine, since the vectors are horizontal.

$C=3000\text{ N}-2000\text{ N}=1000\text{ N}; D=3000\text{ N}+2000\text{ N}=5000\text{ N}$

To find the magnitude of the net force on objects A and B, we use the Pythagorean theorem.

$\text{A}=\sqrt{(3000\text{ N})^2+(2000\text{ N})^2}=3600\text{ N}=\text{B}$

So far, we have C, A = B, D (from smallest magnitude to largest). We must estimate the net force on object E. The angle that the longer vector makes with the horizontal is approximately 60°.Using this estimate we find the magnitudes of the components.

$\text{E}_x=(3000\text{ N})\cos60°=1500\text{ N};\ \text{E}_y=(3000\text{ N})\sin60°=2600\text{ N}$

We have a net horizontal component of 500 N. Use the Pythagorean theorem to find the magnitude of the net force on object E.

$\text{E}=\sqrt{(500\text{ N})^2+(2600\text{ N})^2}=2650\text{ N}$

From smallest to largest, the magnitudes of the net forces are $\boxed{\text{C, E, A = B, D}}$.

32. Strategy All the forces are in the vertical direction. The force of the tibia pushing down on the ankle joint must be equal in magnitude and opposite in direction to the tension in the Achilles tendon pulling up on the ankle joint plus the normal force due to the ground pushing up on the ball of the foot.

Solution Find the force exerted on the foot by the tibia.

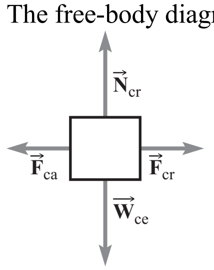
$$(2230\text{ N} + 750\text{ N})\text{ down} = \boxed{2980\text{ N down}}$$

33. Strategy Since the mattress is neither moving upward nor downward, the net force must be zero in the vertical direction.

Solution So that the net force is zero, the upward force of the water must be equal to the combined weight of the man and the air mattress, or $\boxed{806\text{ N}}$.

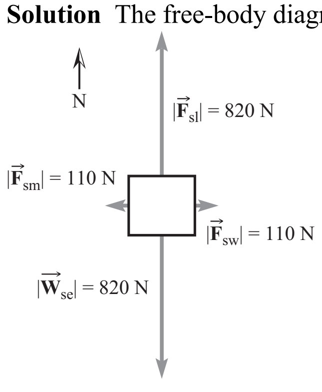
34. Strategy The car is moving straight with constant speed, so the horizontal pair of forces and the vertical pair of forces are equal in magnitude and opposite in direction. Let the subscripts be the following:
c = car e = Earth r = road a = air

Solution Since the car is moving with constant velocity, the net force on the car is zero.
The free-body diagram is shown.



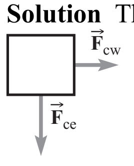
35. Strategy The force of the lake on the boat must be equal in magnitude and opposite in direction to the weight of the boat. The force of the wind on the boat must be equal in magnitude and opposite in direction to that of the line. Let the subscripts be the following:
s = sailboat e = Earth w = wind l = lake m = mooring line

Solution The free-body diagram is shown.



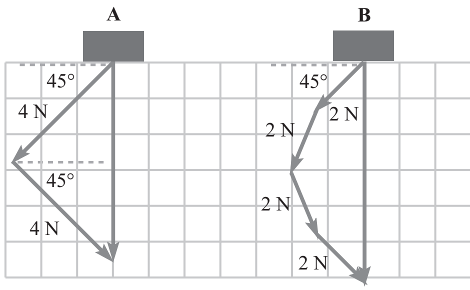
36. Strategy Assume that the (now crashed) car has completely come to rest against the wall. There are two bodies exerting forces on the car, the wall and the Earth. Let the subscripts be the following:
c = car e = Earth w = wall

Solution The free-body diagram is shown.



37. Strategy Make a scale drawing to determine which net force is greater.

Solution The scale drawing is shown.



The net force magnitude on object B is greater than that on object A because two of the forces acting on B are directed at an angle greater than 45° with respect to the horizontal and contribute more to the downward-directed net force.

38. Strategy For each object, add the forces to find the net force.

Solution

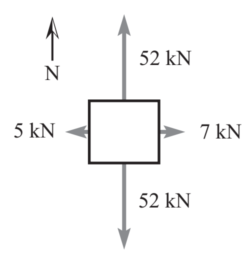
(a) 10 N left + 40 N right = -10 N right + 40 N right = $\boxed{\text{30 N to the right}}$

(b) The forces balance, so the net force is $\boxed{0}$.

(c) The horizontal forces balance, so the net force is due only to the downward force. The net force is $\boxed{\text{18 N downward}}$.

39. Strategy Draw a free-body diagram and add the force to find the net force on the truck.

Solution The vertically directed forces balance, so the net force is due to the difference in the east-west forces.
7 kN east + 5 kN west = 7 kN east − 5 kN east = $\boxed{\text{2 kN east}}$



40. Strategy Use the properties of vectors to answer the questions.

Solution

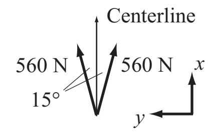
(a) The only way for the net force to have a magnitude of 7.0 N is if the two forces are in the $\boxed{\text{same direction}}$.

(b) Recognizing that the three vectors form a 3-4-5 right triangle, we know that the vectors are $\boxed{\text{perpendicular}}$.

(c) The smallest magnitude net force can only be obtained if the two vectors are in $\boxed{\text{opposite directions}}$; the magnitude of the smallest net force is $\boxed{\text{1.0 N}}$.

41. Strategy Use Newton's laws of motion. Let the *y*-direction be perpendicular to the canal and the +*x*-direction be parallel to the center line in the direction of motion.

Solution Find the sum of the two forces on the barge.



$\sum F_y = T\sin 15° - T\sin 15° = 0$ and

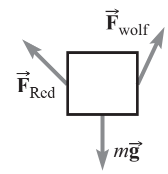
$\sum F_x = T\cos 15° + T\cos 15° = 2T\cos 15° = 2(560\text{ N})\cos 15° = 1.1\text{ kN}.$

So, $\vec{\mathbf{F}} = \boxed{1.1\text{ kN forward (along the center line)}}$.

No; there are other forces acting on the barge, which are not included.

42. Strategy Draw a free-body diagram. Then, solve for the angle Red Riding Hood was pulling such that the net force on the basket is straight up.

Solution Since we don't know all quantities, the vectors in the diagram are not to scale. For the net force to be straight up, the net force in the horizontal direction must be zero. Only the forces due to Red and the wolf have components in the horizontal direction, so these components must be equal in magnitude but opposite in direction. Set these components equal and solve for the angle. Since the angle is measured from the vertical, the horizontal component of the wolf's force is the magnitude times the sine of the angle (and similarly for Red's force).



$(12\text{ N})\sin\theta = (6.4\text{ N})\sin 25°$

$$\theta = \sin^{-1}\frac{(6.4\text{ N})\sin 25°}{12\text{ N}} = \boxed{13° \text{ from the vertical}}$$

43. Strategy and Solution The towline and glider are interaction partners; thus, according to Newton's third law of motion, the forces they exert on each other are equal in magnitude and opposite in direction. Therefore, the force exerted by the glider on the towline is 850 N, due west.

44. Strategy Since the hummingbird is hovering motionless, there is no net force on the hummingbird.

Solution The force exerted on the air by the hummingbird is equal in magnitude and opposite in direction to the upward force exerted by the air; thus, the force exerted on the air is 0.30 N down.

45. Strategy Consider forces acting on the fish suspended by the line.

Solution

One force acting on the fish is an upward force on the fish by the line; its interaction partner is a downward force on the line by the fish. A second force acting on the fish is the downward gravitational force on the fish; its interaction partner is the upward gravitational force on the Earth by the fish.

46. Strategy Consider forces acting on the rod.

Solution

One force acting on the rod is the downward force on the rod by the line; its interaction partner is the upward force on the line by the rod. Another force acting on the rod is the downward gravitational force on the rod by the Earth; its interaction partner is the upward gravitational force on the Earth by the rod.

47. **Strategy** Use Newton's first and third laws.

Solution

(a) Margie exerts a downward force on the scale equal to her weight, 543 N. According to the third law, the scale exerts an upward force on Margie equal in magnitude to the magnitude of the force exerted by Margie on it, or $\boxed{543\text{ N}}$.

(b) Refer to part (a). The interaction partner of the force exerted on Margie by the scale is the [contact force of Margie's feet] on the scale.

(c) The floor must hold up both the scale and (indirectly) Margie, since Margie is standing on the scale. So, the floor must push up on the scale with a force equal to the combined weight of Margie and the scale, or $543\text{ N} + 45\text{ N} = \boxed{588\text{ N}}$.

(d) Refer to part (c). The interaction partner of the force exerted on the scale by the Earth is [the contact force on the Earth due to the scale].

48. **Strategy** We are concerned with the interactions of pairs of objects that exert forces on each other. Analyze the forces in light of Newton's first and third laws.

Solution

(a) Forces [(a) and (b) are third law pairs]. This is an interaction between two objects, the bike and the Earth. Each body exerts a gravitational force on the other body; and these forces are equal in magnitude and opposite in direction.

(b) Forces [(a) and (c) are equal and opposite due to the first law]. These two bodies exert forces that act not on each other, but on a third body.

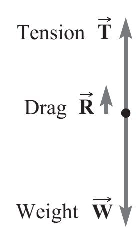
49. **(a)** **Strategy** Identify each force acting on the skydiver.

Solution

Gravitational force exerted on the skydiver by Earth; drag exerted on the skydiver by the air; tension exerted on the skydiver by the parachute.

(b) **Strategy** Draw an FBD using the force information in part (a).

Solution The FBD for the forces exerted on the skydiver is shown at right.



(c) **Strategy** Determine the magnitude of the force exerted by the air using the force of the parachute and the weight of the skydiver.

Solution Both the upward tension force exerted by the parachute and the upward drag force exerted by the air act to oppose the downward force due to gravity exerted on the skydiver (the weight). Since the skydiver is falling at constant speed, the net force on the skydiver is zero. Thus, the sum of the magnitudes of the upward forces must be equal to that of the skydiver's weight. So, $F_{\text{air}} + 620\text{ N} = 650\text{ N}$, or $F_{\text{air}} = \boxed{30\text{ N}}$.

(d) **Strategy** Use Newton's laws to identify the interaction partners of each force acting on the skydiver.

Solution

Gravitational force exerted on Earth by the skydiver, 650 N upward; drag exerted on the air by the skydiver, 30 N downward; tension exerted on the parachute by the skydiver, 620 N downward.

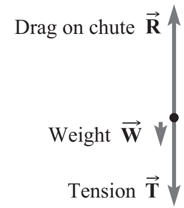
50. (a) Strategy Identify each force acting on the parachute.

Solution

Drag is exerted on the parachute by the air; tension is exerted on the parachute by the skydiver; gravity (weight) is exerted on the parachute by Earth.

(b) Strategy Draw an FBD using the force information in part (a).

Solution The FBD for the forces exerted on the parachute is shown at right.



(c) Strategy Since the skydiver and parachute are falling at constant speed, the net force on the system is zero. Thus, the force on the parachute due to the skydiver is equal in magnitude and opposite in direction to the force exerted on the skydiver due to the parachute.

Solution Since the force exerted on the skydiver due to the parachute is 620 N upward, the force exerted on the parachute due to the skydiver is 620 N downward.

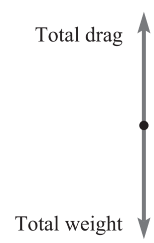
(d) Strategy Use Newton's laws to identify the interaction partners of each force acting on the parachute.

Solution

Tension is exerted on the skydiver by the parachute; drag is exerted on the air by the parachute; gravity is exerted on Earth by the parachute.

51. Strategy Treat the skydiver and parachute as a single system.

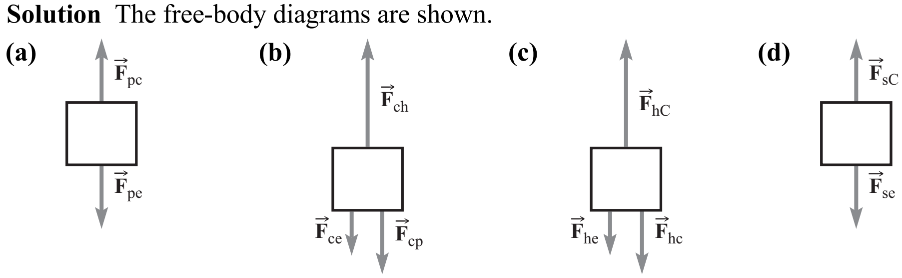
Solution The two external forces acting on the skydiver and parachute system are the upward directed drag force due to the air (total drag) and the downward directed force due to gravity (total weight). The magnitudes are equal. The FBD is shown at right.



52. Strategy Draw vector arrows representing all of the forces acting on the object. Make sure that the directions of the arrows correctly illustrate the directions of the forces and that their lengths are proportional to the magnitudes of the forces. Let the subscripts be the following:

p = system of plant, soil, pot h = hook c = cord C = ceiling
e = Earth s = system of plant, soil, pot, cord, hook

Solution The free-body diagrams are shown.



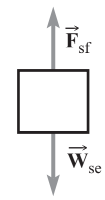
53. Strategy Analyze the forces due to and on the three interacting objects: the woman, the chair, and the floor.

Solution

(a) The weight of the woman is directed downward. The forces on the woman due to the seat and armrests are directed upward and total 25 N + 25 N + 500 N = 550 N. The chair and floor must support her entire weight, so the balance of her weight to support is $600\text{ N} - 2(25\text{ N}) - 500\text{ N} = 50\text{ N}.$ Thus, the floor exerts a force on the woman's feet of $\boxed{50.0\text{ N upward}}$.

(b) The force exerted by the floor on the chair must be equal to the weight of the chair plus the weight of the woman supported by the chair, or 600.0 N + 100.0 N − 50.0 N = 650.0 N. Thus, the floor exerts a force on the chair of $\boxed{650.0\text{ N upward}}$.

(c) The two forces acting on the woman and chair system are the upward force due to the floor and the downward gravitational force due to the Earth. Let the subscripts be the following: s = woman and chair system, e = Earth, f = floor.



54. Strategy Use the conversion factor for pounds to newtons, $1\text{ lb} = 4.448\text{ N},$ and the Earth's average gravitational field strength, $g = 9.80\text{ N/kg}.$

Solution

(a) Answers will vary. For a 150-lb person, $(150\text{ lb})(4.448\text{ N/lb}) = \boxed{670\text{ N}}.$

(b) Weight of 250 g of cheese $= mg = (0.25\text{ kg})(9.80\text{ N/kg}) = \boxed{2.5\text{ N}}$

(c) Answers will vary. A stick of butter weighs about 0.25 lb.
$(0.25\text{ lb})(4.448\text{ N/lb}) = 1.1\text{ N}$
So, $\boxed{\text{a stick of butter}}$ weighs about 1 N.

55. Strategy Use the conversion factor for pounds to newtons, $0.2248\text{ lb} = 1\text{ N}.$

Solution

(a) Find the weight of the girl in newtons.
$W = mg = (40.0\text{ kg})(9.80\text{ N/kg}) = \boxed{392\text{ N}}$

(b) Find the weight of the girl in pounds.
$(392\text{ N})(0.2248\text{ lb/N}) = \boxed{88.1\text{ lb}}$

56. Strategy Find the mass using the weight of the man and the Earth's average gravitational field strength, $g = 9.80\text{ N/kg}.$

Solution Find the mass of the man.

$$m = \frac{W}{g} = \frac{0.80\times10^3\text{ N}}{9.80\text{ N/kg}} = \boxed{82\text{ kg}}$$

57. Strategy Use Newton's universal law of gravitation. The Voyager spacecraft are approximately 17 billion kilometers from the Sun. Use this value for the distance between the Earth and the spacecraft.

Solution Find the approximate magnitude of the gravitational force between Earth and the spacecraft.

$$F = \frac{Gm_1m_2}{r^2} = \frac{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(825\ \text{kg})(5.974\times10^{24}\ \text{kg})}{(17\times10^{12}\ \text{m})^2} = \boxed{1.1\times10^{-9}\ \text{N}}$$

58. Strategy Gravitational field strength is given by $g = GM/R^2$, so let the new field strength be $g' = ng = GM/r^2$, where $n = 2/3$ for part (a) and $1/3$ for part (b).

Solution Determine *r* in terms of *R*.

$$\frac{g'}{g} = \frac{ng}{g} = n = \frac{\frac{GM}{r^2}}{\frac{GM}{R^2}} = \frac{R^2}{r^2},\ \text{so}\ r = \frac{R}{\sqrt{n}}.$$

Find an expression for the altitude, *h*.

$$h = r - R = \frac{R}{\sqrt{n}} - R = R\left(\frac{1}{\sqrt{n}} - 1\right)$$

(a) $h = (6.371\times10^3\ \text{km})\left(\frac{1}{\sqrt{2/3}} - 1\right) = \boxed{1432\ \text{km}}$

(b) $h = (6.371\times10^3\ \text{km})\left(\frac{1}{\sqrt{1/3}} - 1\right) = \boxed{4664\ \text{km}}$

59. Strategy On Earth, $g = 9.80\ \text{N/kg}$.

Solution Find the man's weight on Earth, Mars, Venus, and Earth's moon.

$mg = (65\ \text{kg})(9.80\ \text{N/kg}) = \boxed{640\ \text{N}}$

(a) Find the man's weight on Mars.

$mg = (65\ \text{kg})(3.7\ \text{N/kg}) = \boxed{240\ \text{N}}$

(b) Find the man's weight on Venus.

$mg = (65\ \text{kg})(8.9\ \text{N/kg}) = \boxed{580\ \text{N}}$

(c) Find the man's weight on Earth's moon.

$mg = (65\ \text{kg})(1.6\ \text{N/kg}) = \boxed{100\ \text{N}}$

60. Strategy This is the same as asking, "At what altitude is the gravitational field strength half of its value at the surface of the Earth?" $g = GM/R^2$, so let the new field strength be $g' = ng = GM/r^2$ where $n = 1/2$.

Solution Determine *r* in terms of *R*.

$$\frac{g'}{g} = \frac{ng}{g} = n = \frac{\frac{GM}{r^2}}{\frac{GM}{R^2}} = \frac{R^2}{r^2},\ \text{so}\ r = \frac{R}{\sqrt{n}}.$$

Find an expression for the altitude, *h*.

$$h = r - R = \frac{R}{\sqrt{n}} - R = R\left(\frac{1}{\sqrt{n}} - 1\right),\ \text{so}\ h = (6.371\times10^3\ \text{km})\left(\frac{1}{\sqrt{1/2}} - 1\right) = \boxed{2639\ \text{km}}.$$

61. Strategy Gravitational field strength is given by $g = GM/R^2$. Find $H = R_2 - R_1$, where R_1 and R_2 are the distances from the center of the Earth to the surface of the Earth and the location of the balloon, respectively.

Solution Find the height above sea level of the balloon, *H*.

$$H = R_2 - R_1 = \sqrt{\frac{GM}{g_2}} - \sqrt{\frac{GM}{g_1}} = \sqrt{GM}\left(g_2^{-1/2} - g_1^{-1/2}\right)$$

$$= \sqrt{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.974\times10^{24}\ \text{kg})}\left[(9.792\ \text{N/kg})^{-1/2} - (9.803\ \text{N/kg})^{-1/2}\right] = \boxed{4\ \text{km}}$$

62. Strategy The gravitational field strength is given by $g = GM/R^2$. Use the mass of the Earth and the gravitational field strength of the Moon and solve for *R*, which, in this case, is the distance from the center of the Earth. Then, subtract the radius of the Earth to find the height above the surface.

Solution Solving for *R*, we have

$$R = \sqrt{\frac{GM}{g}} = \sqrt{\frac{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.974\times10^{24}\ \text{kg})}{1.62\ \text{m/s}^2}} = 1.57\times10^4\ \text{km}.$$

So, the height above the surface is $1.57\times10^4\ \text{km} - 6.371\times10^3\ \text{km} = \boxed{9.3\times10^3\ \text{km}}$.

63. (a) Strategy Compare the strengths of the forces at the location of the rock.

Solution The gravitational force between to bodies is inversely proportional to the square of the distance between them. The Moon is much closer to the rock than is the Earth, so (even though the Earth is much more massive than the Moon) the rock will fall toward the Moon's surface.

(b) Strategy The Moon's gravitational field strength is $1.62\ \text{N/kg}$. The force of the Moon on the rock is equal to the weight of the rock on the Moon.

Solution Find the weight of the rock to find the gravitational force exerted by the Moon on it.

$$F = W = mg = (1.0\ \text{kg})(1.62\ \text{N/kg}) = 1.6\ \text{N}$$

The force on the rock due to the Moon is 1.6 N toward the Moon.

(c) Strategy Use Newton's law of universal gravitation. The average Earth-Moon distance is 3.845×10^8 m. The mass of the Earth is 5.974×10^{24} kg.

Solution Find the gravitational force exerted by the Earth on the rock.

$$F = \frac{Gm_1m_2}{r^2} = \frac{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(1.0\ \text{kg})(5.974\times10^{24}\ \text{kg})}{(3.845\times10^8\ \text{m})^2} = 2.7\ \text{mN}$$

Since gravitational force is attractive, the force exerted by the Earth on the rock is 2.7 mN toward Earth.

(d) Strategy Recognize that the force due to the Moon is much greater than that due to the Earth.

Solution Find the net gravitational force.

$$1.6\ \text{N toward the Moon} + 0.0027\ \text{N toward Earth} = 1.6\ \text{N toward the Moon} - 0.0027\ \text{N toward the Moon}$$
$$= \boxed{1.6\ \text{N toward the Moon}}$$

64. (a) Strategy Use Newton's universal law of gravitation and $r = 3.845\times10^8\text{ m}$ for the distance between Earth and the Moon.

Solution Find the magnitude of the gravitational force that Earth exerts on the Moon.

$$F = \frac{GM_\text{E}M_\text{M}}{r^2} = \frac{(6.674\times10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(5.974\times10^{24}\text{ kg})(7.35\times10^{22}\text{ kg})}{(3.845\times10^8\text{ m})^2} = \boxed{1.98\times10^{20}\text{ N}}$$

(b) Strategy Use Newton's third law.

Solution According to Newton's third law, the magnitude of the gravitational force that the moon exerts on the Earth is $\boxed{\text{the same}}$ as the force that the Earth exerts on the moon.

65. Strategy Use Newton's universal law of gravitation.

Solution Find the ratio.

$$\frac{F_1}{F_2} = \frac{Gm_1m_2}{r_1^2} \div \frac{Gm_1m_2}{r_2^2} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{r_1 + 6.00\times10^6\text{ m}}{r_1}\right)^2 = \left(\frac{6.371\times10^6\text{ m} + 6.00\times10^6\text{ m}}{6.371\times10^6\text{ m}}\right)^2 = \boxed{3.770}$$

66. (a) Strategy Use Newton's universal law of gravitation and $3.845\times10^8\text{ m}$ for the distance between Earth and the Moon; $1.50\times10^{11}\text{ m} + 3.845\times10^8\text{ m}$ for the distance between the Sun and the Moon. During a lunar eclipse, the gravitational forces due to the Sun and Earth on the Moon add.

Solution Find the magnitude of the net gravitational force.

$$F = \frac{GM_\text{S}M_\text{M}}{r_\text{MS}^2} + \frac{GM_\text{E}M_\text{M}}{r_\text{ME}^2} = GM_\text{M}\left(\frac{M_\text{S}}{r_\text{MS}^2} + \frac{M_\text{E}}{r_\text{ME}^2}\right)$$

$$= (6.674\times10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(7.349\times10^{22}\text{ kg})\left[\frac{1.987\times10^{30}\text{ kg}}{(1.50\times10^{11}\text{ m} + 3.845\times10^8\text{ m})^2} + \frac{5.974\times10^{24}\text{ kg}}{(3.845\times10^8\text{ m})^2}\right]$$

$$= \boxed{6.29\times10^{20}\text{ N}}$$

(b) Strategy Use Newton's universal law of gravitation and $3.845\times10^8\text{ m}$ for the distance between Earth and the Moon; $1.50\times10^{11}\text{ m} - 3.845\times10^8\text{ m}$ for the distance between the Sun and the Moon. During a solar eclipse, the gravitational forces due to the Sun and Earth on the Moon subtract.

Solution Find the magnitude of the net gravitational force.

$$F = \frac{GM_\text{S}M_\text{M}}{r_\text{MS}^2} - \frac{GM_\text{E}M_\text{M}}{r_\text{ME}^2} = GM_\text{M}\left(\frac{M_\text{S}}{r_\text{MS}^2} - \frac{M_\text{E}}{r_\text{ME}^2}\right)$$

$$= (6.674\times10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(7.349\times10^{22}\text{ kg})\left[\frac{1.987\times10^{30}\text{ kg}}{(1.50\times10^{11}\text{ m} - 3.845\times10^8\text{ m})^2} - \frac{5.974\times10^{24}\text{ kg}}{(3.845\times10^8\text{ m})^2}\right]$$

$$= \boxed{2.37\times10^{20}\text{ N}}$$

67. Strategy Consider each of the four forces and any possible relationships between them.

Solution (a) The force of the Earth pulling on the book and (d) the force of the book pulling on the Earth are an interaction pair; they are equal and opposite. (b) The force of the table pushing on the book and (c) the force of the book pushing on the table are an interaction pair; they are equal and opposite. There are two forces acting on the book: the gravitational force of Earth pulling on it and the contact force of the table pushing on it. Since the book is in equilibrium, the net force on it must be zero; therefore, the forces due to Earth and the table on the book are equal and opposite, so the pair of forces given in (a) and (b) are equal in magnitude and opposite in direction even though they are not an interaction pair.

68. Strategy Consider each object and its relationships to the others.

Solution

(a) The table must support the weights of both the dictionary and Fernando, so the normal force exerted by the table on the dictionary is $N = m_1g + m_2g = (m_1 + m_2)g = (2.0\text{ kg} + 52\text{ kg})(9.80\text{ N/kg}) = \boxed{530\text{ N}}$.

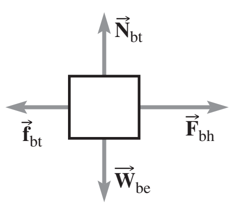
(b) The dictionary must support the weight of Fernando, so the normal force exerted by the dictionary on Fernando is $N = mg = (52\text{ kg})(9.80\text{ N/kg}) = \boxed{510\text{ N}}$.

(c) Fernando and the table are not in contact, so no, there is not a normal force exerted by the table on Fernando.

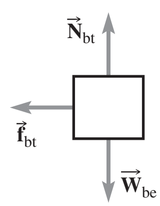
69. Strategy Draw free-body diagrams for each situation. Let the subscripts be the following:
b = book t = table e = Earth h = hand

Solution The diagrams are shown.

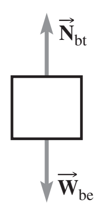
(a)



(b)



(c)



(d) Strategy and Solution In cases (a) and (b), the book is accelerating; so in these cases, the net force is not zero.

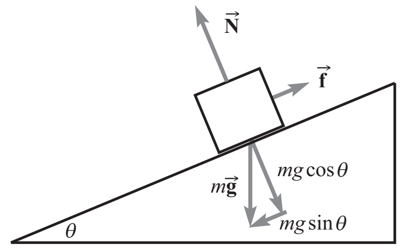
(e) Strategy and Solution The normal force on the book is equal to its weight, $(0.50\text{ kg})(9.80\text{ m/s}^2) = 4.9\text{ N}$. The net force acting on the book in part (b) is equal to the force of kinetic friction. The force of kinetic friction is opposite the direction of motion. The magnitude is $\mu_k N = 0.40(4.9\text{ N}) = 2.0\text{ N}$. Thus, the net force on the book is 2.0 N opposite the direction of motion.

(f) Strategy and Solution The free-body diagram would look just like the diagram for part (c) and the book would not slow down because there is no net force on the book (friction is zero).

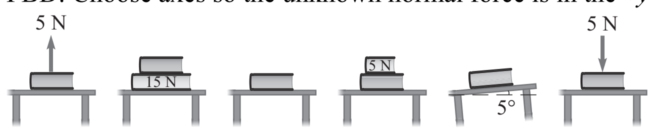
70. Strategy To just get the block to move, the magnitude of the gravitational force acting on the box must be equal to the magnitude of the maximum force of static friction. See the free-body diagram.

Solution Find the angle of the ramp.

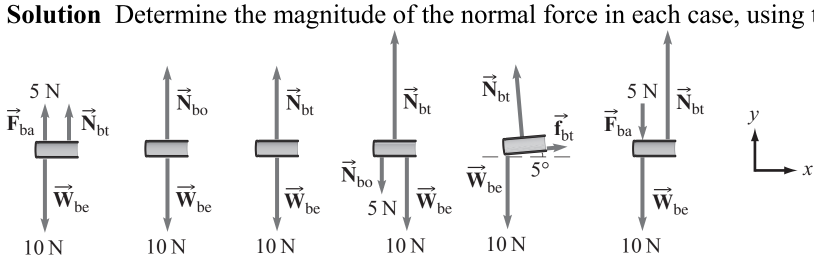
$$mg\sin\theta = f_{\text{max}}$$
$$= \mu_s N$$
$$= \mu_s mg\cos\theta$$
$$\tan\theta = \mu_s$$
$$\theta = \tan^{-1}\mu_s = \tan^{-1}0.30 = \boxed{17°}$$



71. Strategy Determine the magnitude of the normal force on the book due to the table in each case by setting the net force on the book equal to zero. In each case, start by identifying the forces acting on the book and drawing an FBD. Choose axes so the unknown normal force is in the +*y*-direction.



Solution Determine the magnitude of the normal force in each case, using the FBDs below.



Now find N_{bt} by setting the net force in the *y*-direction equal to zero.

(a) N_{bt} is smaller than the weight of the book (10 N) due to the applied force pulling up (N_{bt} = 5 N).

(b) N_{bt} = 0 because the table is not touching the book, so it can't exert a contact force on it. (There *is* a normal force due to the 15-N book.)

(c) N_{bt} is equal to the weight of the book (N_{bt} = 10 N).

(d) N_{bt} is larger than the weight of the book due to the contact force of the 5-N book pushing down. The 5-N book is also in equilibrium, so the contact force is 5 N and N_{bt} = 15 N.

(e) N_{bt} is equal to the *y*-component of the weight, so it is *slightly* less than 10 N, or (10 N)cos 5°.

(f) N_{bt} is the same as in (d)—it doesn't matter whether the applied force of 5 N downward is due to a book sitting on top of it or something else.

From smallest to greatest, $\boxed{\text{(b), (a), (e), (c), (d) = (f)}}$.

72. Strategy Since the crate is at rest, the net force on it must be zero. The force of static friction must oppose the force of gravity parallel to the ramp. The normal force must oppose the force of gravity perpendicular to the ramp.

Solution Find the magnitude of the normal force and the magnitude and direction of the force of static friction.

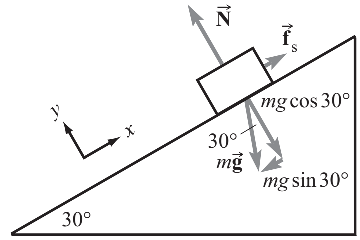
$\sum F_y = N - mg\cos\theta = 0$, so

$N = mg\cos\theta = (18.0 \text{ kg})(9.80 \text{ N/kg})\cos 30° = \boxed{150 \text{ N}}$.

$\sum F_x = f_s - mg\sin\theta = 0$, so

$f_s = mg\sin\theta = (18.0 \text{ kg})(9.80 \text{ N/kg})\sin 30° = 88 \text{ N}$.

The force of static friction is $\boxed{\text{88 N up the ramp}}$.



73. Strategy The crate is sliding down the ramp. The force of kinetic friction must oppose the motion of the crate parallel to the ramp. The normal force must oppose the force of gravity perpendicular to the ramp.

Solution Find the magnitude of the normal force and the magnitude and direction of the force of kinetic friction.

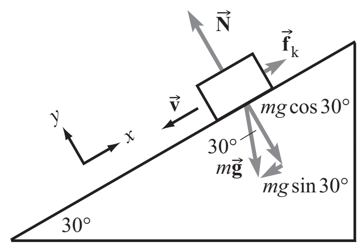
$\sum F_y = N - mg\cos\theta = 0$, so

$N = mg\cos\theta = (18.0 \text{ kg})(9.80 \text{ N/kg})\cos 30° = \boxed{150 \text{ N}}$.

$\sum F_x = f_k = \mu_k N = \mu_k mg\cos\theta$, so

$f_k = 0.40(18.0 \text{ kg})(9.80 \text{ N/kg})\cos 30° = 61 \text{ N}$.

The force of kinetic friction is $\boxed{\text{61 N up the ramp}}$.



74. Strategy The crate is sliding *up* the ramp. The force of kinetic friction must oppose the motion of the crate parallel to the ramp. The normal force must oppose the force of gravity perpendicular to the ramp.

Solution Find the magnitude of the normal force and the magnitude and direction of the force of kinetic friction.

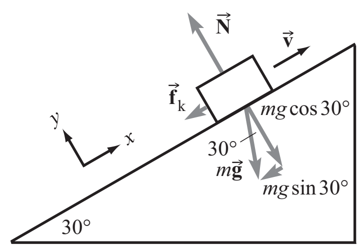
$\sum F_y = N - mg\cos\theta = 0$, so

$N = mg\cos\theta = (18.0 \text{ kg})(9.80 \text{ N/kg})\cos 30° = \boxed{150 \text{ N}}$.

$\sum F_x = f_k = \mu_k N = \mu_k mg\cos\theta$, so

$f_k = 0.40(18.0 \text{ kg})(9.80 \text{ N/kg})\cos 30° = 61 \text{ N}$.

The force of kinetic friction is $\boxed{\text{61 N down the ramp}}$.



75. Strategy The crate is moving at constant speed up the ramp on the conveyor belt (without sliding), so the net force on it is zero. The force of static friction must oppose the force of gravity parallel to the ramp (and conveyor belt). The normal force must oppose the force of gravity perpendicular to the ramp (and conveyor belt).

Solution Find the magnitude of the normal force and the magnitude and direction of the force of static friction.

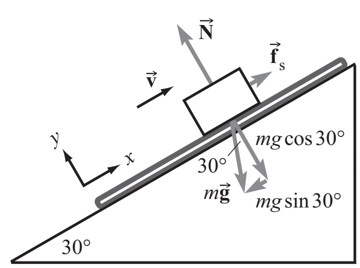
$\sum F_y = N - mg\cos\theta = 0$, so

$N = mg\cos\theta = (18.0 \text{ kg})(9.80 \text{ N/kg})\cos 30° = \boxed{150 \text{ N}}$.

$\sum F_x = f_s - mg\sin\theta = 0$, so

$f_s = mg\sin\theta = (18.0 \text{ kg})(9.80 \text{ N/kg})\sin 30° = 88 \text{ N}$.

The force of static friction is $\boxed{\text{88 N up the ramp}}$.



76. Strategy The direction of the normal force is always perpendicular to the surface of the ramp. The friction force is in whatever direction necessary to oppose the motion of the object.

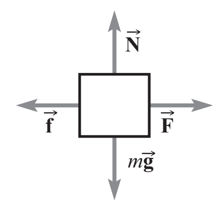
Solution The results are shown in the table.

	$\vec{\mathbf{N}}$	$\vec{\mathbf{f}}$
(a)	perpendicular to and away from	along the ramp upward
(b)	perpendicular to and away from	along the ramp downward
(c)	perpendicular to and away from	along the ramp upward

77. (a) Strategy To just get the block to move, the force must be equal to the maximum force of static friction.

Solution Solve for μ_s.

$$F = f_{max} = \mu_s N = \mu_s mg, \text{ so } \mu_s = \frac{F}{mg} = \frac{12.0 \text{ N}}{(3.0 \text{ kg})(9.80 \text{ N/kg})} = \boxed{0.41}.$$



(b) Strategy The maximum static frictional force is now proportional to the total mass of the two blocks. The free-body diagram is the same as before, except that the mass *m* is now the sum of the masses of both blocks.

Solution Find the magnitude *F* of the force required to make the two blocks start to move.

$$F = \mu_s mg = 0.41(3.0 \text{ kg} + 7.0 \text{ kg})(9.80 \text{ N/kg}) = \boxed{40 \text{ N}}$$

78. (a) Strategy Use Newton's first law of motion.

Solution Since the sleigh is moving with constant speed, the net force acting on the sleigh is $\boxed{\text{zero}}$.

(b) Strategy Since $F_{net} = 0,$ the force of magnitude *T* must be equal to the force of kinetic friction.

Solution Find the coefficient of kinetic friction.

$$T = f_k = \mu_k mg, \text{ so } \mu_k = \boxed{\frac{T}{mg}}.$$

79. Strategy Since the block moves with constant speed, there is no net force on the block. Draw the free-body diagram using this information. Let the subscripts be the following:
b = block B = Brenda w = wall e = Earth

Solution Find the coefficient of kinetic friction between the wall and the block.

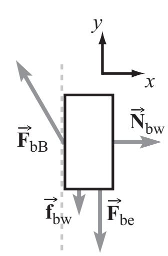
$$\sum F_x = N_{bw} - F_{bB} \sin\theta = 0, \text{ so } N_{bw} = F_{bB} \sin\theta.$$

$$\sum F_y = F_{bB} \cos\theta - F_{be} - f_{bw} = 0, \text{ so } f_{bw} = F_{bB} \cos\theta - F_{be}.$$

Since $f_{bw} = \mu_k N_{bw}$, we have

$$\mu_k = \frac{F_{bB}\cos\theta - F_{be}}{N_{bw}} = \frac{F_{bB}\cos\theta - F_{be}}{F_{bB}\sin\theta} = \cot\theta - \frac{F_{be}}{F_{bB}}\csc\theta$$

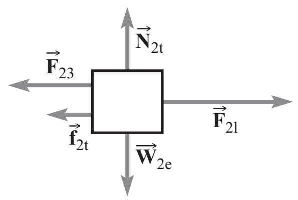
$$= \cot 30.0° - \frac{2.0 \text{ N}}{3.0 \text{ N}}\csc 30.0° = \boxed{0.4}$$



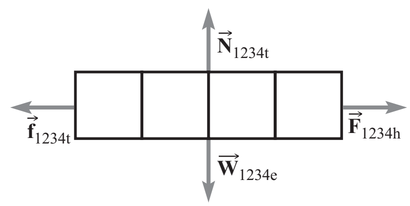
80. Strategy Let the subscripts be the following:
t = table e = Earth 1 = block 1 2 = block 2 3 = block 3 4 = block 4
h = horizontal force 1234 = system of blocks (The blocks are numbered from left to right.)

Solution The diagrams are shown.

(a)



(b)



81. (a) Strategy and Solution Since the apples neither slide nor roll as they move up the incline, the apples are not moving relative to the belt, so the belt exerts forces of static friction on the apples.

(b) Strategy and Solution The apples are in equilibrium; therefore, the force of static friction is equal to 0.40 N, and we cannot conclude anything about the coefficient of kinetic friction. Find the coefficient of static friction.

$$f_s \leq \mu_s N, \text{ so } \mu_s \geq \frac{f_s}{N} = \frac{0.40\text{ N}}{1.0\text{ N}} = \boxed{0.40}.$$

82. (a) Strategy Refer to Example 2.14. The maximum static friction force must be greater than the *x*-component of the weight. Use Newton's laws of motion.

Solution

$\sum F_x = f_s - mg\sin\theta \geq 0$, so $f_s \geq mg\sin\theta$ and $\sum F_y = N - mg\cos\theta = 0$, so $N = mg\cos\theta$.

Compare the forces of friction and gravity.

$$\begin{aligned} \mu_s N &\geq mg\sin\theta \\ \mu_s mg\cos\theta &\geq mg\sin\theta \\ \mu_s &\geq \tan\theta \\ 0.42 &\geq \tan 15° \\ 0.42 &\geq 0.27 \quad \text{True} \end{aligned}$$

Yes; the static friction force can hold the safe in place.

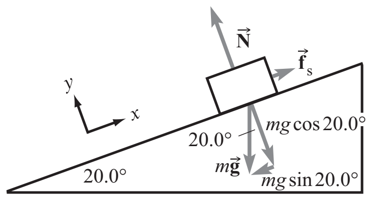
(b) Part (b) is unnecessary, since the answer to part (a) is yes.

83. Strategy Use Newton's laws of motion.

Solution Without a machine, the force is equal to the weight of the object *mg*. According to Newton's laws of motion and Fig. 2.32, with a frictionless plane, the force is equal to $mg\sin\phi = mg\frac{h}{d}$. So, $\frac{mg}{mg\frac{h}{d}} = \frac{d}{h}$.

84. Strategy Use Newton's laws of motion. Draw a diagram.

Solution



(a) Compute the magnitude of the normal force.

$\sum F_y = N - mg\cos\theta = 0,$ so $N = mg\cos\theta = (80.0\text{ N})\cos 20.0° = 75.2\text{ N}.$

The normal force is 75.2 N perpendicular to and above the surface of the ramp.

(b) The interaction partner is equal in magnitude to the component of the apple crate's weight perpendicular to the ramp, 75.2 N perpendicular to the ramp and opposite in direction to the normal force; it is exerted by the crate on the ramp; it is a contact force.

(c) Compute the magnitude of the force of static friction on the crate.

$\sum F_x = f_s - mg\sin\theta = 0,$ so $f_s = mg\sin\theta = (80.0\text{ N})\sin 20.0° = 27.4\text{ N}.$

The force of static friction exerted on the crate by the ramp is 27.4 N up the incline.

(d) The minimum possible value of the coefficient of static friction is the value that just makes the force of static friction oppose the component of the crate's weight that is directed down the incline.

$$f_s = \mu_{s,\text{ min}} N = mg\sin\theta, \text{ so } \mu_{s,\text{ min}} = \frac{mg\sin\theta}{N} = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta = \tan 20.0° = \boxed{0.364}.$$

(e) Find the magnitude.

$$F = \sqrt{f_s^2 + N^2} = \sqrt{(27.4\text{ N})^2 + (75.2\text{ N})^2} = 80.0\text{ N}$$

Find the direction.

$$\theta = \tan^{-1}\frac{N}{f} = \tan^{-1}\frac{mg\cos\theta}{mg\sin\theta} = \tan^{-1}\frac{1}{\tan 20.0°} = 70.0° \text{ or upward}$$

So, $\vec{\mathbf{F}} = \boxed{80.0\text{ N upward}}$.

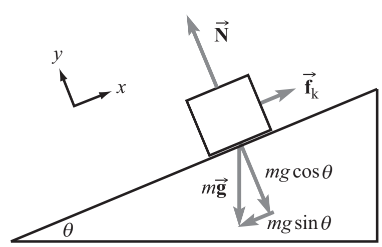
85. (a) Strategy Draw a diagram and use Newton's laws of motion.

Solution According to the first law, since the skier is moving with constant velocity, the net force on the skier is zero. Calculate the force of kinetic friction.

$\sum F_x = f_k - mg\sin\theta = 0,$ so

$f_k = mg\sin\theta = (85\text{ kg})(9.80\text{ N/kg})\sin 11° = 160\text{ N}.$

The force of kinetic friction is 160 N up the slope.



(b) Strategy Use the diagram and results from part (a).

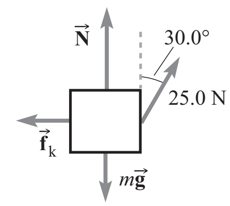
Solution Find the normal force.

$\sum F_y = N - mg\cos\theta = 0,$ so $N = mg\cos\theta.$ Since $f_k = \mu_k N,$

$$\mu_k = \frac{f_k}{N} = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta = \tan 11° = \boxed{0.19}.$$

86. Strategy Since the suitcase is moving at a constant speed, the net force on it must be zero. The force of friction must oppose the force of the pull. So, the force of friction must be equal in magnitude and opposite in direction to the horizontal component of the force of the pull. Draw a free-body diagram to illustrate the situation.

Solution Find the force of friction.



The horizontal component of the pull force is $(25.0\text{ N})\sin 30.0° = 12.5\text{ N}$. Since the horizontal component of the pull force is equal and opposite to the friction force, the force of friction acting on the suitcase is $\boxed{12.5\text{ N, opposite the direction of motion}}$.

87. Strategy Recall that the tension in the rope is the same along its length.

Solution The tension is equal to the weight at the end of the rope, 120 N. Therefore, $\boxed{\text{scale A reads 120 N}}$.

There are two forces pulling downward on the pulley due to the tension of 120 N in each part of the rope. Therefore, $T_B = T_A + T_A = 2T_A = 240\text{ N}$. $\boxed{\text{Scale B reads 240 N}}$, since it supports the pulley.

88. Strategy Recall that the tension in the rope is the same along its length.

Solution The tension is equal to the weight at the end of the rope, 120 N. Therefore, $\boxed{\text{both scales read 120 N}}$.

89. Strategy Use Newton's laws of motion.

Solution The Earth exerts a force on the mass, which then exerts a force on the scale, which then exerts a force on the hook, which then exerts a force on the ceiling. All these forces are equal (assuming that the masses of the spring scale and hook are negligible). In addition, each body, on which a force is exerted, exerts an equal and opposite force on the other object. So, the ceiling exerts a force on the hook, the hook on the scale, etc. One person replaces the force on the mass due to the Earth, and the other person replaces the force on the scale due to the hook. So, each person must exert a force of $\boxed{98\text{ N}}$.

90. Strategy Use Newton's laws of motion and analyze each scale separately.

Solution $\boxed{\text{Scale B reads 120 N}}$ due to the apples hanging from it. According to Newton's third law, $\boxed{\text{scale A also reads 120 N,}}$ since B is attached directly below it, which is attached to the weight.

91. Strategy Use Newton's laws of motion. The lower cord supports only the lower box, whereas the upper cord supports both boxes. Draw a diagram.

Solution Find the tension in each cord.

Lower cord

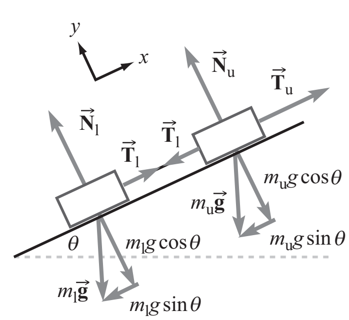
$\sum F_x = T_l - m_l g\sin\theta = 0$, so

$T_l = m_l g\sin\theta = (2.0\text{ kg})(9.80\text{ N/kg})\sin 25° = \boxed{8.3\text{ N}}$.

Upper cord

$\sum F_x = T_u - m_u g\sin\theta - T_l = 0$, so

$T_u = m_u g\sin\theta + T_l = (1.0\text{ kg})(9.80\text{ N/kg})\sin 25° + 8.3\text{ N} = \boxed{12.4\text{ N}}$.

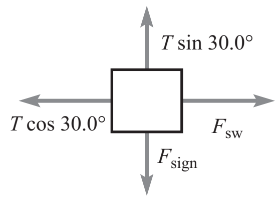


92. Strategy Identify all forces acting on the strut. Decompose the tension into its x- and y-components.

Solution Use Newton's laws of motion. See the diagram.

$\sum F_y = T\sin 30.0° - 200.0\text{ N} = 0$, so

$T = \dfrac{200.0\text{ N}}{\sin 30.0°} = \boxed{400\text{ N}}$.



93. Strategy Use Newton's laws of motion. Let $+y$ be down and $+x$ to the right.

Solution Find the force $\vec{\mathbf{F}}$ applied to the front tooth.

$\sum F_x = T\sin\theta - T\sin\theta = 0$ and $\sum F_y = T\cos\theta + T\cos\theta - F = 0$. So, we have

$F = 2T\cos\theta = 2(12\text{ N})\cos 37.5° = 19\text{ N}$. By symmetry, the force is directed toward the back of the mouth, so

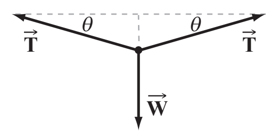
$\vec{\mathbf{F}} = \boxed{19\text{ N toward the back of the mouth}}$.

94. Strategy Use Newton's laws of motion. Draw a diagram.

Solution Find the tension.

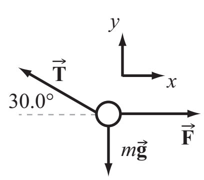
$\sum F_x = T\cos\theta - T\cos\theta = 0$ and

$\sum F_y = T\sin\theta + T\sin\theta - W = 0$. So, $2T\sin\theta = W$, or $T = \boxed{\dfrac{W}{2\sin\theta}}$.



95. Strategy Use Newton's law of motion. Draw a free-body diagram.

Solution



(a) $\sum F_x = F - T\cos\theta = 0$, so $F = T\cos\theta$. $\sum F_y = T\sin\theta - mg = 0$, so $T\sin\theta = mg$, or $T = mg/\sin\theta$.

Thus, $F = \dfrac{mg}{\sin\theta}\cos\theta = \dfrac{mg}{\tan\theta} = \dfrac{(2.0\text{ kg})(9.80\text{ N/kg})}{\tan 30.0°} = \boxed{34\text{ N}}$.

(b) $T = \dfrac{(2.0\text{ kg})(9.80\text{ N/kg})}{\sin 30.0°} = \boxed{39\text{ N}}$

96. Strategy Use Newton's laws of motion. Draw a free-body diagram.

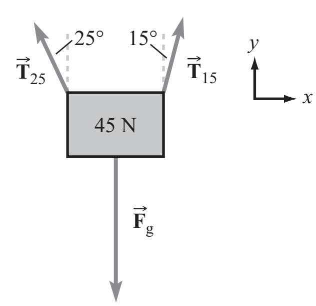
Solution Find the tension in each wire.

$\sum F_x = T_{25}\sin 25° - T_{15}\sin 15° = 0$, so $T_{25}\sin 25° = T_{15}\sin 15°$, or

$T_{25} = \dfrac{\sin 15°}{\sin 25°}T_{15}$.

$\sum F_y = T_{25}\cos 25° + T_{15}\cos 15° - F = 0$, so $T_{15}\cos 15° + T_{25}\cos 25° = F$.

Substitute for T_{25}.



$$T_{15}\cos 15° + \left(\frac{\sin 15°}{\sin 25°}T_{15}\right)\cos 25° = F$$

$$T_{15}\left(\cos 15° + \frac{\sin 15°}{\tan 25°}\right) = F$$

$$T_{15} = \frac{45\text{ N}}{\cos 15° + \sin 15°/\tan 25°} = \boxed{30\text{ N}}$$

$$T_{25} = \frac{\sin 15°}{\sin 25°}(30\text{ N}) = \boxed{18\text{ N}}$$

97. Strategy Use Newton's laws of motion. Draw a free-body diagram.

Solution

(a) Find the tension in the rope from which the pulley hangs.

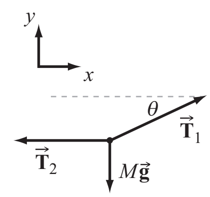
$\sum F_y = T_1\sin\theta - Mg = 0$ and $\sum F_x = T_1\cos\theta - T_2 = 0.$

The tension in T_2 is due to the mass M, so $T_2 = Mg.$

Thus, $T_1\cos\theta = Mg$ and $T_1\sin\theta = Mg.$

According to these equations, $\cos\theta = \sin\theta$, which is true only if $\theta = 45°$ for $0° \le \theta \le 90°.$

Therefore, $T_1 = Mg/\cos 45° = \boxed{\sqrt{2}Mg}.$



(b) As found in part (a), $\theta = \boxed{45°}.$

98. Strategy Consider the fundamental forces and their relative strengths.

Solution The gravitational force is the fundamental force that governs the motion of planets in the solar system. Gravity is by far the weakest of the fundamental forces, though it dominates interactions at large scales primarily because planets and larger bodies are extremely massive. The electromagnetic force is ineffective for such bodies because they are electrically neutral. The final two fundamental forces, the weak and strong nuclear forces, dominate interactions at very small distance scales, but have no effect on the large distance scales associated with the motion of large bodies.

99. Strategy Consider the ranges of the forces given.

Solution The range of the strong force is about 10^{-15} m, so it certainly does not have unlimited range. Contact forces are not unlimited, as well, since they are limited to the contact region between objects (and there are no known objects of unlimited size). Both electromagnetic and gravitational forces have unlimited ranges.

100. Strategy Consider the nature of the forces given.

Solution The strong force holds protons and neutrons together in the atomic nucleus, and its range is much smaller than the radius of an atom; thus, it is not the force that binds electrons to nuclei to form atoms. When atoms on the surfaces of two objects come very close together, they interact via the electromagnetic force. These are contact forces. So, contact force is an interaction *between* atoms, not *within* atoms; thus, it is not the force that binds electrons to nuclei. Nuclei and electrons have masses so small that the gravitational forces between them are vanishingly small; so, gravitational force is not the force that binds electrons to nuclei. So, we are left with electromagnetism as the force that is the fundamental interaction that binds electrons to nuclei to form atoms.

101. Strategy Consider the ranges and natures of the fundamental forces.

Solution Of all of the fundamental forces, the weak force has the shortest range (about 10^{-17} m). In the Sun, the weak interaction enables thermonuclear reactions to occur, without which there would be no sunlight.

102. Strategy Consider the natures of the fundamental forces.

Solution Of the fundamental forces, the strong force is the strongest, hence its name. It is strong, but has a very short range. But the range is just the right size (about 10^{-15} m) to be the fundamental interaction that binds quarks together to form protons, neutrons, and many exotic subatomic particles.

103. Strategy Use Newton's laws of motion.

Solution

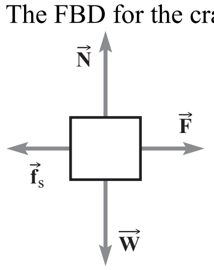
(a) The forces acting on the crate are the following:

The gravitational force exerted on the crate by Earth; the normal force exerted on the crate by the floor; the contact force exerted on the crate by Phineas; static friction exerted on the crate by the floor.

(b) The interaction partners of each force acting on the crate are the following:

The gravitational force exerted on Earth by the crate; the normal force exerted on the floor by the crate; the contact force exerted on Phineas by the crate; static friction exerted on the floor by the crate.

(c) The FBD for the crate:



Only external forces acting on an object are shown in a free-body diagram (FBD).
So no, only the forces acting on the crate are shown in the FBD.

(d) The crate is not accelerating; therefore, the net force acting on the crate is zero. Because of this, the normal force exerted on the crate by the floor is equal in magnitude to the weight of the crate; and the force of static friction exerted on the crate by the floor is equal in magnitude to the force exerted on the crate by Phineas. The magnitudes of the forces exerted on the crate are:

weight = normal force = 350 N; force exerted by Phineas = static friction = 150 N

(e) Only forces acting *on* the crate are shown in the FBD, not interaction partners which are forces due to the crate; so no; these forces are equal and opposite because the net force on the crate is zero.

104. Strategy Analyze the forces for each situation. The tension must never exceed 12 N.

Solution Find the tension in each wire. Refer to the diagram.

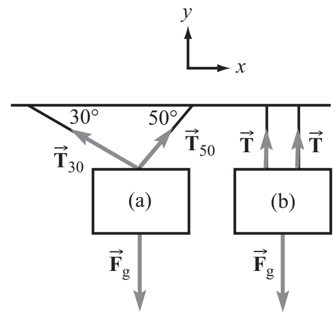


Figure (a)

$$\sum F_x = T_{50}\cos 50° - T_{30}\cos 30° = 0, \text{ so } T_{30} = \frac{\cos 50°}{\cos 30°}T_{50}.$$

$$\sum F_y = T_{30}\sin 30° + T_{50}\sin 50° - F_g = 0, \text{ so } T_{30}\sin 30° + T_{50}\sin 50° = F_g.$$

Substitute for T_{30}.

$$\left(\frac{\cos 50°}{\cos 30°}T_{50}\right)\sin 30° + T_{50}\sin 50° = F_g$$

$$T_{50}(\cos 50° \tan 30° + \sin 50°) = F_g$$

$$T_{50} = \frac{15\text{ N}}{\cos 50° \tan 30° + \sin 50°} = 13\text{ N}$$

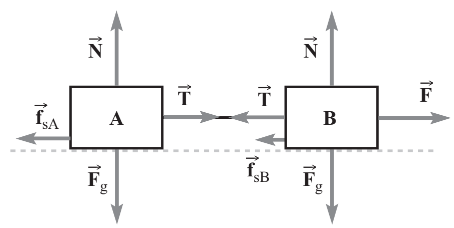
$$T_{30} = \frac{\cos 50°}{\cos 30°}(13.2\text{ N}) = 9.8\text{ N}$$

Figure (b)

$\sum F_y = T + T - F_g = 0$, so $2T = F_g$, or $T = (15\text{ N})/2 = 7.5\text{ N}$. Since 13 N > 12 N, the arrangement in Fig. (a) breaks the twine. Since 7.5 N < 12 N, the arrangement in Fig. (b) successfully hangs the picture.

105. Strategy Draw a diagram and use Newton's laws of motion.

Solution



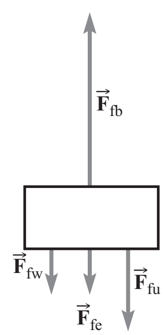
(a) The magnitude of the force of static friction on block A due to the floor must be equal to the magnitude of the tension in the cord, so $T = f_{sA} = \mu_A N = \mu_A mg$.
The magnitude of the applied force must be equal to the magnitude of the tension in the cord plus the magnitude of the force of static friction on block B due to the floor. Thus,

$$F = T + f_{sB} = \mu_A mg + \mu_B mg = mg(\mu_A + \mu_B)$$
$$= (2.0\text{ kg})(9.80\text{ N/kg})(0.45 + 0.30) = \boxed{15\text{ N}}.$$

(b) $T = \mu_A mg = 0.45(2.0\text{ kg})(9.80\text{ N/kg}) = \boxed{8.8\text{ N}}$

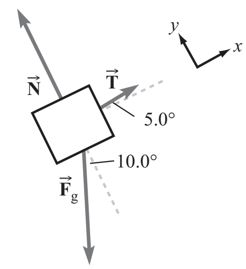
106. Strategy The forces on the forearm in addition to that of the biceps are gravity due to the Earth, a downward force due to the upper arm bone, and the downward force due to the 100-N weight. Let the subscripts be the following: f = forearm, e = Earth, b = biceps, w = weight, u = upper arm bone.

Solution The free-body diagram is shown.



107. (a) Strategy Ignore frictional forces. Identify all of the forces acting on the car; then draw a free-body diagram.

Solution The forces are the normal force due to the road, the gravitational force due to Earth, and the tension due to the rope. The diagram is shown.



(b) Strategy and Solution

Choose the coordinate system with the x-axis in the direction of the slope and the y-axis in the direction of the normal force. Then the problem can be solved just by summing the forces in the x-direction—we don't need to find the normal force so there is no need to sum the forces in the y-direction!

(c) Strategy Use Newton's laws of motion and the free-body diagram

Solution Since the sled is moving at constant velocity up the slope, the vector sum of all forces is zero. In the x-direction, the component of gravity down the slope and the component of the tension in the direction of the slope have to add up to zero. The slope is at 10.0° to the horizontal; and the rope is at 15.0° to the horizontal (5.0° to the slope). Find the tension.

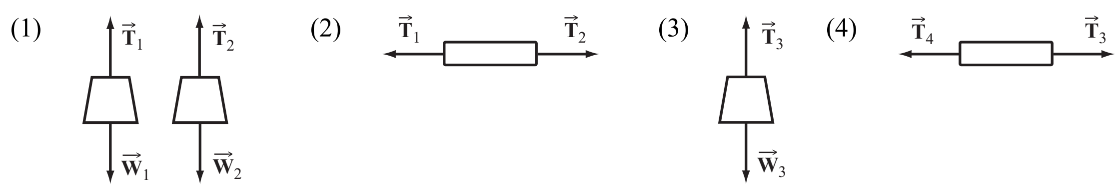
$\sum F_x = T_x - F_{gx} = T\cos 5.0° - mg\sin 10.0° = 0,$ so

$$T = \frac{mg\sin 10.0°}{\cos 5.0°} = \frac{(1250 \text{ kg})(9.80 \text{ N/kg})\sin 10.0°}{\cos 5.0°} = \boxed{2100 \text{ N}}.$$

108. Strategy Use Newton's laws of motion. Draw diagrams.

Solution

(a) Below are two diagrams for each of the two cases.



Sum the forces in (1).

Left weight: $\sum F_y = T_1 - W_1 = 0,$ so $T_1 = W_1 = 550$ N.

Right weight: $\sum F_y = T_2 - W_2 = 0,$ so $T_2 = W_2 = 550$ N.

Since $W_1 = W_2,$ $T_1 = T_2 = 550$ N; the tensions are the same, and the scale in (2) has forces exerted on it of magnitude 550 N, which are opposite in direction.

Sum the forces in (3).

Single weight: $\sum F_y = T_3 - W_3 = 0,$ so $T_3 = W_3 = 550$ N. The scale in (4) is in equilibrium, so $T_4 = T_3 = 550$ N.

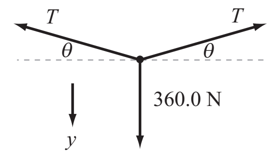
Both scales are in equilibrium and each has two forces which are equal in magnitude and opposite in direction exerted on it. The magnitudes of the forces are equal, so in each case, the two ropes pull on the scale with forces of 550 N in opposite directions, so the scales give the same reading.

(b) The reading on each scale is equal to the tension in the rope, $\boxed{550 \text{ N}}$.

109. Strategy Let the +y-direction be in the direction of the 360.0-N force (F). Draw a diagram and use Newton's laws of motion.

Solution Find the force exerted on the poplar tree.

$\sum F_y = F - 2T\sin\theta = 0$ before the poplar is cut through.



So, $F = 2T\sin\theta$. The force exerted on the poplar is the tension T, so $T = \dfrac{F}{2\sin\theta}$.

Refer to the figure in the text to find $\sin\theta$.

$$\sin\theta = \frac{\text{displacement}}{\text{half length of rope}} = \frac{2.00\text{ m}}{\sqrt{(20.0\text{ m})^2 + (2.00\text{ m})^2}} = 0.0995$$

Thus, $T = \dfrac{360.0\text{ N}}{2(0.0995)} = \boxed{1810\text{ N}}$. Compare the forces.

$\dfrac{1810\text{ N}}{360.0\text{ N}} \approx$ 5 times the force with which Yoojin pulls

The values for the two situations are different because the oak tree supplies additional force.

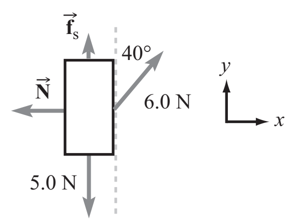
110. Strategy Consider the nature of normal and friction forces. Use Newton's laws of motion.

Solution

(a) The normal force exerted by the hand is directed toward the wall. (The normal force must be perpendicular to the plane of the picture.)

(b) The normal force exerted by the wall on the picture is opposite that due to the hand; it is away from the wall.

(c) The y-component of the force of the hand is $(6.0\text{ N})\cos 40° = 4.6\text{ N}$. This is less than the weight of the painting, so the force of friction has a magnitude of $5.0\text{ N} - 4.6\text{ N} = 0.4\text{ N}$ and points in the positive y-direction. (See the diagram.) The normal force is equal to the x-component of the force of the hand, which is $(6.0\text{ N})\sin 40° = 3.9\text{ N}$.

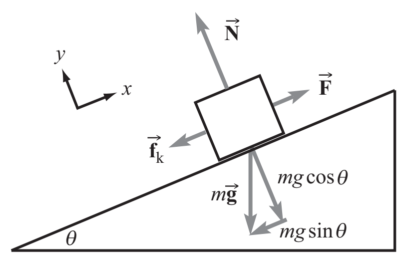


Since $f_s = \mu_s N$, $\mu_s = \dfrac{f_s}{N} = \dfrac{0.4\text{ N}}{3.9\text{ N}} = \boxed{0.1}$.

If the frictional force on the picture exerted by the hand is less than the force exerted on the picture due to gravity, the frictional force on the picture due to the wall is directed upward so that the net vertical force is zero. If the frictional force exerted by the hand is greater than that due to gravity, the force due to the wall is directed downward for the same reason.

111. Strategy Draw a diagram and use Newton's laws of motion.

Solution According to the first law, for the box to move with constant speed, the net force on the box must by zero. Calculate the magnitude of the force of the push required.



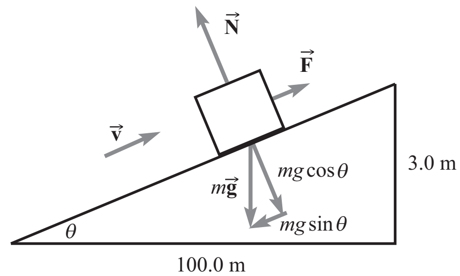
$\sum F_y = N - mg\cos\theta = 0$, so $N = mg\cos\theta$.

$\sum F_x = F - f_k - mg\sin\theta = 0$, so

$$\begin{aligned} F &= f_k + mg\sin\theta = \mu_k N + mg\sin\theta \\ &= \mu_k mg\cos\theta + mg\sin\theta = mg(\mu_k\cos\theta + \sin\theta) \\ &= (65\text{ kg})(9.80\text{ N/kg})(0.30\cos 25° + \sin 25°) = \boxed{440\text{ N}}. \end{aligned}$$

112. Strategy Use Newton's laws of motion. Neglect friction and draw a diagram. The slope of the incline is equal to $\tan\theta$. Let $+x$ be up the incline.

Solution Find the magnitude of the force exerted on the rollercoaster by the chain.



$\sum F_y = 0$

$\sum F_x = F - mg\sin\theta = 0,$ since the speed is constant.

Thus, $F = mg\sin\theta = mg\sin\left(\tan^{-1}\dfrac{\Delta y}{\Delta x}\right)$

$= (400.0\text{ kg})(9.80\text{ N/kg})\sin\left(\tan^{-1}\dfrac{3.0\text{ m}}{100.0\text{ m}}\right) = \boxed{120\text{ N}}.$

113. Strategy Use Newton's laws of motion.

Solution

(a) Since the airplane is cruising in a horizontal level flight (straight line) at constant velocity, it is in equilibrium and the net force is $\boxed{\text{zero}}$.

(b) The air pushes upward with a force equal to the weight of the airplane: $\boxed{2.6\times10^4\text{ N}}$.

114. Strategy Use Newton's laws of motion. Let the $+y$-direction be up and the $+x$-direction be to the right.

Solution

(a) The tension T is the same along the length of the cord. Its magnitude is equal to the weight of the leg (and the weight of the hanging weight), 22 N. The only vertical force is due to this tension, so $F_y = 22$ N.

Find the magnitude of the total force of the traction apparatus applied to the leg.

$\sum F_x = T\cos\theta + T\cos\theta - F_x = 0,$ so $F_x = 2T\cos\theta = 2(22\text{ N})\cos 30.0° = 38\text{ N}.$

Thus, $F = \sqrt{(38\text{ N})^2 + (22\text{ N})^2} = \boxed{44\text{ N}}.$

(b) The horizontal force is $F_x = \boxed{38\text{ N}}.$

(c) The magnitude of the horizontal force acting on the femur is equal to the horizontal component of the traction force acting on the leg, $F_x = \boxed{38\text{ N}}.$

115. Strategy Use Newton's laws of motion. Let the $+y$-direction be up and the $+x$-direction be to the right. Since the tibia is at a 30.0° angle below the horizontal, the force due to the patellar tendon on the tibia is at an angle 20.0° + 30.0° = 50.0° above the horizontal.

Solution Find the components of the force exerted on the tibia by the femur.

$\sum F_y = (337\text{ N})\sin 50.0° - (3.00\text{ kg} + 5.00\text{ kg}) - F_y = 0,$ so $F_y = (337\text{ N})\sin 50.0° - 8.00\text{ kg} = 179.76\text{ N}.$

$\sum F_x = F_x - (337\text{ N})\cos 50.0° = 0,$ so $F_x = (337\text{ N})\cos 50.0° = 216.62\text{ N}.$

Find the magnitude and direction of the force.

$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(216.62\text{ N})^2 + (179.76\text{ N})^2} = \boxed{281\text{ N}}$

$\theta = \tan^{-1}\dfrac{F_y}{F_x} = \tan^{-1}\dfrac{179.76\text{ N}}{216.62\text{ N}} = \boxed{39.7°\text{ below the horizontal to the right}}$

116. (a) Strategy The force on the patella bisects the angle between the directions of the tension of the tendons. So, the angle is $(37.0° + 80.0°)/2 = 58.5°$. Use Newton's laws of motion.

Solution Find the magnitude of the contact force exerted on the patella by the femur.
$\Sigma F = F - T\cos\theta - T\cos\theta = 0$, so $F = 2T\cos\theta = 2(1.30\text{ kN})\cos 58.5° = \boxed{1360\text{ N}}$.

(b) Strategy Refer to part (a).

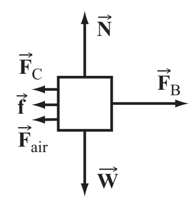
Solution Find the direction of the contact force.
$\theta = 58.5° - 37.0° = 80.0° - 58.5° = \boxed{21.5°}$

117. Strategy Use Newton's laws of motion.

Solution

(a) Since the train is moving at constant speed, and air resistance and friction are negligible, the readings on the three scales are $\boxed{\text{all } 0}$.

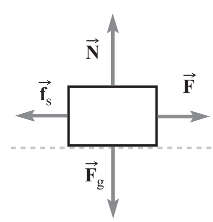
(b) Air resistance and friction are not considered negligible this time. The engine pulls the cars against these forces. Since the cars are identical, each car contributes about one-third of the total frictional and drag forces. Each spring scale will measure the net force due to the cars behind it, so the relative readings on the three spring scales are $\boxed{A > B > C}$. The free-body diagram is shown.



(c) Spring A measures the forces on all 3 cars. Spring B measures the forces on the latter 2 cars. Spring C measures the forces on the final 1 car.
A = 5.5 N + 5.5 N + 5.5 N = $\boxed{16.5\text{ N}}$; B = 5.5 N + 5.5 N = $\boxed{11.0\text{ N}}$; C = $\boxed{5.5\text{ N}}$

118. (a) Strategy The force required to start the block moving is that needed to overcome the maximum force of static friction. Draw a diagram.

Solution Find the applied horizontal force.
$\sum F_x = F - f_s = 0$, so $F = f_s = \mu_s N$.
$\sum F_y = N - F_g = N - mg = 0$, so $N = mg$.
So, the value of the applied force at the instant that the block starts to slide is $F = \mu_s mg = 0.40(5.0\text{ kg})(9.80\text{ N/kg}) = \boxed{20\text{ N}}$.

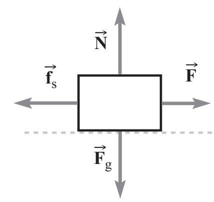


(b) Strategy The force required to keep the block moving is that needed to overcome kinetic friction. At the instant the block starts to slide, the net force on the block is the difference between the forces required to overcome static and kinetic friction.

Solution Calculate the net force.
$\sum F = f_s - f_k = \mu_s mg - \mu_k mg = (\mu_s - \mu_k)mg = (0.40 - 0.15)(5.0\text{ kg})(9.80\text{ N/kg}) = \boxed{12\text{ N}}$

119. (a) Strategy The force of static friction is greater than the applied force. Draw a diagram.

Solution Find the possible values for the coefficient of static friction.



$f_s = \mu_s N > F$, so $\mu_s > \dfrac{F}{N} = \dfrac{120\text{ N}}{250\text{ N}} = 0.48.$

Therefore, $\boxed{\mu_s > 0.48}$.

(b) Strategy Refer to part (a).

Solution Compute the coefficient of static friction.

$\mu_s = F/N = (150\text{ N})/(250\text{ N}) = \boxed{0.60}$

(c) Strategy Refer to part (a), but with the coefficient of kinetic friction instead of that for static friction.

Solution Compute the coefficient of kinetic friction.

$\mu_k = F/N = (120\text{ N})/(250\text{ N}) = \boxed{0.48}$

120. (a) Strategy The tension due to the weight of the potatoes is divided evenly between the two sets of scales.

Solution Find the tension and, thus, the reading of each scale.

$2T = mg$, so $T = mg/2 = (220.0\text{ N})/2 = \boxed{110.0\text{ N}}$.

(b) Strategy Scales B and D will read 110.0 N as before. Scales A and C will read an additional 5.0 N due to the weights of B and D, respectively.

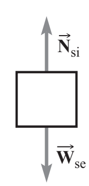
Solution Find the reading of each scale.

$T_A = 110.0\text{ N} + 5.0\text{ N} = \boxed{115.0\text{ N}} = T_C$ and $T_B = \boxed{110.0\text{ N}} = T_D$.

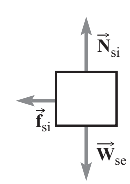
121. Strategy Let the subscripts be the following:
i = ice e = Earth s = stone o = opponent's stone

Solution

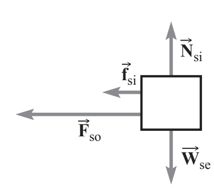
(a) The only forces on the stone are gravity due to the Earth and the normal force due to the ice.



(b) As the stone slides down the rink, it experiences a force of kinetic friction opposite to its motion.



(c) The additional force is that due to the opponent's stone.



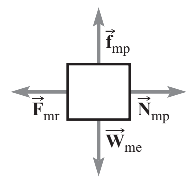
122. (a) Strategy Identify the interactions between the magnet and other objects.

Solution The interactions are:

1) The gravitational forces between the magnet and Earth
2) The contact forces, normal and frictional, between the magnet and the photo
3) The magnetic forces between the magnet and the refrigerator

(b) Strategy Refer to part (a). Let the subscripts be the following:
m = magnet p = photo e = Earth r = refrigerator

Solution The magnet is in equilibrium, so the horizontal pair of forces and the vertical pair of forces are equal in magnitude and opposite in direction.



(c) Strategy Identify the range of each force and categorize each as long-range or contact.

Solution
The long-range forces are gravity and magnetism. The contact forces are friction and the normal force.

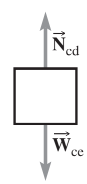
(d) Strategy Refer to part (b). W_{me} and F_{mr} are given.

Solution

$W_{me} = 0.14$ N, $F_{mr} = 2.10$ N, $f_{mp} = W_{me} = 0.14$ N, and $N_{mp} = F_{mr} = 2.10$ N.

123. (a) Strategy Let the subscripts be the following:
c = computer d = desk e = Earth

Solution The only forces on the computer are gravity due to the Earth and the normal force due to the desk. The free-body diagram is shown.



(b) Strategy Consider the nature of friction forces.

Solution Since the only forces acting on the computer are in the vertical direction, the friction force is zero.

(c) Strategy Find the maximum force of static friction on the computer due to the desk; this is the horizontal force necessary to make it begin to slide.

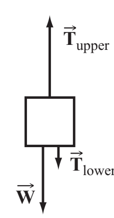
Solution $F = f_s = \mu_s N = \mu_s W = 0.60(87\text{ N}) = \boxed{52\text{ N}}$

124. Strategy The force exerted on the upper scale is the combination of the weight of the crate and the tension of the lower scale. The forces in the vertical direction sum to zero, since the system is in equilibrium. Draw a diagram.

Solution Find the reading of the upper scale.

$0 = T_{upper} - W - T_{lower}$, so

$T_{upper} = W + T_{lower} = mg + 120\text{ N} = (50.0\text{ kg})(9.80\text{ N/kg}) + 120\text{ N} = \boxed{610\text{ N}}$.



125. **(a)** **Strategy** Scale A measures the weight of both masses. Scale B only measures the weight of the 4.0-kg mass.

Solution Find the readings of the two scales if the masses of the scales are negligible.

$\text{Scale A} = (10.0\text{ kg} + 4.0\text{ kg})(9.80\text{ N/kg}) = \boxed{137\text{ N}}$ and $\text{Scale B} = (4.0\text{ kg})(9.80\text{ N/kg}) = \boxed{39\text{ N}}$.

(b) **Strategy** Scale A measures the weight of both masses and scale B. Scale B only measures the weight of the 4.0-kg mass.

Solution Find the readings if each scale has a mass of 1.0 kg.

$\text{Scale A} = (10.0\text{ kg} + 4.0\text{ kg} + 1.0\text{ kg})(9.80\text{ N/kg}) = \boxed{147\text{ N}}$ and $\text{Scale B} = \boxed{39\text{ N}}$.

126. **Strategy** Use the method of Example 2.10.

Solution Find the change in the gravitational field strength.

$$\frac{W}{W_{\text{surface}}} = \frac{g}{g_{\text{surface}}} = \left(1 + \frac{h}{R_{\text{E}}}\right)^{-2}, \text{ so } g = g_{\text{surface}}\left(1 + \frac{h}{R_{\text{E}}}\right)^{-2}.$$

Compute the change in the gravitational field strength.

$$\Delta g = g_{\text{surface}} - g = g_{\text{surface}}\left[1 - \left(1 + \frac{h}{R_{\text{E}}}\right)^{-2}\right] = (9.80\text{ N/kg})\left[1 - \left(1 + \frac{8850\text{ m}}{6.37\times 10^{6}\text{ m}}\right)^{-2}\right] = \boxed{0.027\text{ N/kg}}$$

127. **Strategy** The gravitational field strengths at sea level at the equator and at the North Pole are 9.784 N/kg and 9.832 N/kg, respectively. Weight is directly proportional to *g*.

Solution Find the percentage by which the weight of an object changes when moved from the equator to the North Pole.

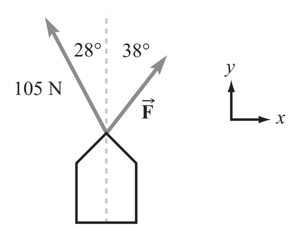
$(9.832 - 9.784)/9.784 \times 100\% = \boxed{0.49\%}$

128. **(a)** **Strategy** For the sum of the two forces to be in the forward (+*y*) direction, the net force in the *x*-direction must be zero. Draw a diagram and use Newton's laws of motion.

Solution Compute the magnitude of the force.

$\sum F_x = F\sin 38° - (105\text{ N})\sin 28° = 0,$ so

$$F = \frac{(105\text{ N})\sin 28°}{\sin 38°} = \boxed{80\text{ N}}.$$



(b) **Strategy** Find the sum of the *y*-components of the two forces to find the magnitude of the net force on the barge from the two tow ropes.

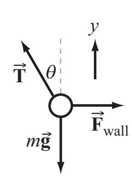
Solution Find the magnitude of the force.

$\sum F_y = F\cos 38° + (105\text{ N})\cos 28° = (80\text{ N})\cos 38° + (105\text{ N})\cos 28° = \boxed{160\text{ N}}$

129. **Strategy** Use Newton's laws of motion and draw a free-body diagram.

Solution Find the tension in the cable.

$$\sum F_y = T\cos\theta - mg = 0, \text{ so } T = \boxed{\frac{mg}{\cos\theta}}.$$



130. Strategy Use Newton's laws of motion. Let $+y$ be up and $+x$ be to the right.

Solution

(a) Find the magnitude of $\vec{\mathbf{F}}_c$.

$$\Sigma F_x = F_m \cos\theta - F_c \cos\phi = 0, \text{ so } F_c = F_m \frac{\cos\theta}{\cos\phi}.$$

$$\Sigma F_y = -F_m \sin\theta + F_c \sin\phi - W = 0, \text{ so } F_c = \frac{W + F_m \sin\theta}{\sin\phi}.$$

Eliminate F_c and solve for ϕ.

$$F_m \frac{\cos\theta}{\cos\phi} = \frac{W + F_m \sin\theta}{\sin\phi}$$

$$\tan\phi = \frac{W + F_m \sin\theta}{F_m \cos\theta} = \frac{W}{F_m \cos\theta} + \tan\theta$$

$$\phi = \tan^{-1}\left(\frac{W}{F_m \cos\theta} + \tan\theta\right) = \tan^{-1}\left[\frac{50.0\text{ N}}{(60.0\text{ N})\cos 35°} + \tan 35°\right] = 60°$$

So, $F_c = (60.0\text{ N})\dfrac{\cos 35°}{\cos 59.8°} = \boxed{98\text{ N}}$.

(b) As found in part (a), $\phi = \boxed{60° \text{ above the horizontal}}$.

131. Strategy Set the magnitudes of the forces on the spaceship due to the Earth and the Moon equal. (The forces are along the same line.)

Solution Find the distance from the Earth expressed as a percentage of the distance between the centers of the Earth and the Moon.

$$F_{sE} = \frac{GM_E m}{r_E^2} = F_{sM} = \frac{GM_M m}{r_M^2}, \text{ so } r_E = r_M \sqrt{\frac{M_E}{0.0123 M_E}} = 9.02 r_M.$$

Find the percentage.

$$\frac{r_E}{r_E + r_M} = \frac{9.02 r_M}{9.02 r_M + r_M} = \frac{9.02}{10.02} = 0.900$$

The distance from the Earth is $\boxed{90.0\% \text{ of the Earth-Moon distance}}$.

132. (a) Strategy Use Newton's law of universal gravitation.

Solution Find the weight of the satellite when in orbit.

$$F_g = \frac{GM_E m}{r^2} = \frac{(6.674\times10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(5.974\times10^{24}\text{ kg})(320\text{ kg})}{(6.371\times10^6\text{ m} + 16{,}000\times10^3\text{ m})^2} = \boxed{250\text{ N}}$$

(b) Strategy The weight on Earth is equal to the satellite's mass times g.

Solution Find the weight of the satellite when it was on the launch pad.

$$F_g = mg = (320\text{ kg})(9.80\text{ N/kg}) = \boxed{3100\text{ N}}$$

(c) Strategy Use Newton's third law of motion.

Solution According to Newton's third law if motion, the satellite exerts a force on the Earth equal and opposite to the force the Earth exerts on it; that is, $\boxed{250\text{ N toward the satellite}}$.

133. (a) Strategy Set the magnitudes of the forces on the spacecraft due to the Earth and the Sun equal.

Solution Find the distance of the spacecraft from Earth.

$$F_{\text{sS}} = \frac{GM_{\text{S}}m}{r_{\text{S}}^2} = F_{\text{sE}} = \frac{GM_{\text{E}}m}{r_{\text{E}}^2}, \text{ so } \frac{r_{\text{E}}}{r_{\text{S}}} = \sqrt{\frac{M_{\text{E}}}{M_{\text{S}}}}.$$

This is the ratio of the Earth-spacecraft distance to the Sun-spacecraft distance. If this is multiplied by the Earth-Sun mean distance, the product is the distance of the spacecraft from the Earth.

$$(1.50\times10^{11}\text{ m})\sqrt{\frac{5.974\times10^{24}\text{ kg}}{1.987\times10^{30}\text{ kg}}} = \boxed{2.60\times10^{8}\text{ m from Earth}}$$

(b) Strategy Imagine the spacecraft is a small distance *d* closer to the Earth and find out which gravitational force is stronger, the Earth's or the Sun's.

Solution At the equilibrium point the net gravitational force is zero. If the spacecraft is closer to the Earth than the equilibrium point distance from the Earth, then the force due to the Earth is greater than that due to the Sun. If the spacecraft is closer to the Sun than the equilibrium point distance from the Sun, then the force due to the Sun is greater than that due to the Earth. So, if the spacecraft is close to, but not at, the equilibrium point, the net force tends to pull it away from the equilibrium point.