acting on the electron is $\Sigma F = F_1 - F_2$. In part *b* of the problem, we will rearrange this expression to obtain the magnitude of the second electric force.

SOLUTION
a. Solving Equation 2.9 for the electron's acceleration, we find that

$$a = \frac{v^2 - v_0^2}{2x} = \frac{\left(+2.10\times10^{6}\ \text{m/s}\right)^2 - \left(+5.40\times10^{5}\ \text{m/s}\right)^2}{2\left(+0.038\ \text{m}\right)} = +5.42\times10^{13}\ \text{m/s}^2$$

Newton's 2nd law of motion then gives the net force causing the acceleration of the electron:

$$\sum F = ma = \left(9.11\times10^{-31}\ \text{kg}\right)\left(+5.42\times10^{13}\ \text{m/s}^2\right) = \boxed{+4.94\times10^{-17}\ \text{N}}$$

b. The net force acting on the electron is $\Sigma F = F_1 - F_2$, so the magnitude of the second electric force is $F_2 = F_1 - \Sigma F$, where ΣF is the net force found in part *a*:

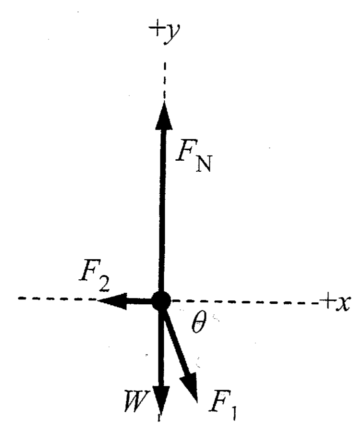
$$F_2 = F_1 - \Sigma F = 7.50\times10^{-17}\ \text{N} - 4.94\times10^{-17}\ \text{N} = \boxed{2.56\times10^{-17}\ \text{N}}$$

---

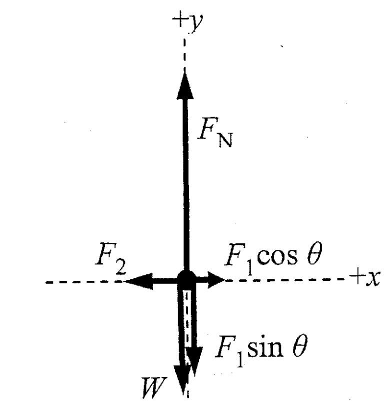
11. ***REASONING*** Newton's second law gives the acceleration as **a** = (S**F**)/*m*. Since we seek only the horizontal acceleration, it is the *x* component of this equation that we will use; $a_x = (SF_x)/m$. For completeness, however, the free-body diagram will include the vertical forces also (the normal force F_N and the weight *W*).

SOLUTION The free-body diagram is shown at the right, where

F_1 = 59.0 N
F_2 = 33.0 N
θ = 70.0°



When F_1 is replaced by its *x* and *y* components, we obtain the free body diagram in the following drawing.



Choosing right to be the positive direction, we have

$$a_x = \frac{\Sigma F_x}{m} = \frac{F_1\cos\theta - F_2}{m}$$

$$a_x = \frac{\left(59.0\ \text{N}\right)\cos 70.0° - \left(33.0\ \text{N}\right)}{7.00\ \text{kg}} = \boxed{-1.83\ \text{m/s}^2}$$

The minus sign indicates that the horizontal acceleration points to the $\boxed{\text{left}}$.

---

12. ***REASONING*** The net force S**F** has a horizontal component SF_x and a vertical component SF_y. Since these components are perpendicular, the Pythagorean theorem applies (Equation 1.7), and the magnitude of the net force is $\Sigma F = \sqrt{\left(\Sigma F_x\right)^2 + \left(\Sigma F_y\right)^2}$. Newton's second law allows us to express the components of the net force acting on the ball in terms of its mass and the horizontal and vertical components of its acceleration: $\Sigma F_x = ma_x$, $\Sigma F_y = ma_y$ (Equations 4.2a and 4.2b).

SOLUTION Combining the Pythagorean theorem with Newton's second law, we obtain the magnitude of the net force acting on the ball:

$$\Sigma F = \sqrt{\left(\Sigma F_x\right)^2 + \left(\Sigma F_y\right)^2} = \sqrt{\left(ma_x\right)^2 + \left(ma_y\right)^2} = m\sqrt{a_x^2 + a_y^2}$$

$$= \left(0.430\ \text{kg}\right)\sqrt{\left(810\ \text{m/s}^2\right)^2 + \left(1100\ \text{m/s}^2\right)^2} = \boxed{590\ \text{N}}$$

---

13. SSM ***REASONING*** To determine the acceleration we will use Newton's second law Σ**F** = m**a**. Two forces act on the rocket, the thrust *T* and the rocket's weight *W*, which is *mg* = (4.50 × 10^5 kg)(9.80 m/s^2) = 4.41 × 10^6 N. Both of these forces must be considered when determining the net force Σ**F**. The direction of the acceleration is the same as the direction of the net force.

SOLUTION In constructing the free-body diagram for the rocket we choose upward and to the right as the positive directions. The free-body diagram is as follows:

44. ***REASONING***
a. Since the refrigerator does not move, the static frictional force must be equal in magnitude, but opposite in direction, to the horizontal pushing force that the person exerts on the refrigerator.

b. The magnitude of the maximum static frictional force is given by Equation 4.7 as $f_s^{MAX} = \mu_s F_N$. This is also the largest possible force that the person can exert on the refrigerator before it begins to move. Thus, the factors that determine this force magnitude are the coefficient of static friction μ_s and the magnitude F_N of the normal force (which is equal to the weight of the refrigerator in this case).

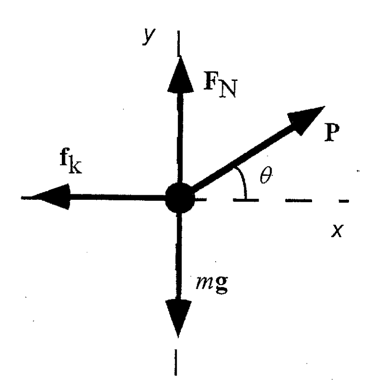
SOLUTION
a. Since the refrigerator does not move, it is in equilibrium, and the magnitude of the static frictional force must be equal to the magnitude of the horizontal pushing force. Thus, the magnitude of the static frictional force is $\boxed{267\text{ N}}$. The direction of this force must be opposite to that of the pushing force, so the static frictional force is in the $\boxed{+x \text{ direction}}$.

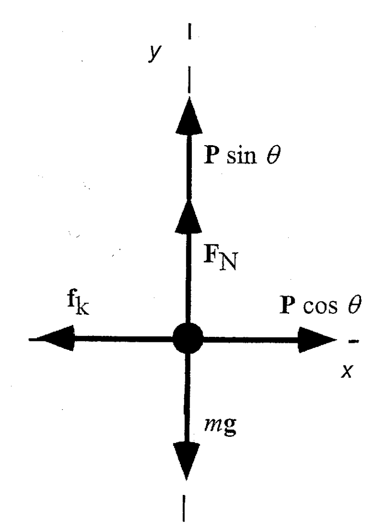
b. The magnitude of the largest pushing force is given by Equation 4.7 as

$$f_s^{MAX} = \mu_s F_N = \mu_s mg = (0.65)(57\text{ kg})(9.80\text{ m/s}^2) = \boxed{360\text{ N}}$$

---

45. SSM ***REASONING AND SOLUTION*** Four forces act on the sled. They are the pulling force **P**, the force of kinetic friction $\mathbf{f}_k$, the weight mg of the sled, and the normal force $\mathbf{F}_N$ exerted on the sled by the surface on which it slides. The following figures show free-body diagrams for the sled. In the diagram on the right, the forces have been resolved into their x and y components.





Since the sled is pulled at constant velocity, its acceleration is zero, and Newton's second law in the direction of motion is (with right chosen as the positive direction)

$$\Sigma F_x = P\cos\theta - f_k = ma_x = 0$$

From Equation 4.8, we know that $f_k = \mu_k F_N$, so that the above expression becomes

$$P\cos\theta - \mu_k F_N = 0 \qquad (1)$$

In the vertical direction,

$$\Sigma F_y = P\sin\theta + F_N - mg = ma_y = 0 \qquad (2)$$

Solving Equation (2) for the normal force, and substituting into Equation (1), we obtain

$$P\cos\theta - \mu_k(mg - P\sin\theta) = 0$$

Solving for μ_k, the coefficient of kinetic friction, we find

$$\mu_k = \frac{P\cos\theta}{mg - P\sin\theta} = \frac{(80.0\text{ N})\cos 30.0^\circ}{(20.0\text{ kg})(9.80\text{ m/s}^2) - (80.0\text{ N})\sin 30.0^\circ} = \boxed{0.444}$$

---

46. ***REASONING*** In each of the three cases under consideration the kinetic frictional force is given by $f_k = \mu_k F_N$. However, the normal force F_N varies from case to case. To determine the normal force, we use Equation 4.6 ($F_N = mg + ma$) and thereby take into account the acceleration of the elevator. The normal force is greatest when the elevator accelerates upward (a positive) and smallest when the elevator accelerates downward (a negative).

SOLUTION
a. When the elevator is stationary, its acceleration is $a = 0\text{ m/s}^2$. Using Equation 4.6, we can express the kinetic frictional force as

$$f_k = \mu_k F_N = \mu_k(mg + ma) = \mu_k m(g + a)$$
$$= (0.360)(6.00\text{ kg})\left[(9.80\text{ m/s}^2) + (0\text{ m/s}^2)\right] = \boxed{21.2\text{ N}}$$

b. When the elevator accelerates upward, $a = +1.20\text{ m/s}^2$. Then,

$$f_k = \mu_k F_N = \mu_k(mg + ma) = \mu_k m(g + a)$$
$$= (0.360)(6.00\text{ kg})\left[(9.80\text{ m/s}^2) + (1.20\text{ m/s}^2)\right] = \boxed{23.8\text{ N}}$$

c. When the elevator accelerates downward, $a = -1.20 \text{ m/s}^2$. Then,

$$f_k = \mu_k F_N = \mu_k\left(mg + ma\right) = \mu_k m\left(g + a\right)$$

$$= (0.360)(6.00 \text{ kg})\left[\left(9.80 \text{ m/s}^2\right) + \left(-1.20 \text{ m/s}^2\right)\right] = \boxed{18.6 \text{ N}}$$

---

47. ***REASONING*** The magnitude of the kinetic frictional force is given by Equation 4.8 as the coefficient of kinetic friction times the magnitude of the normal force. Since the slide into second base is horizontal, the normal force is vertical. It can be evaluated by noting that there is no acceleration in the vertical direction and, therefore, the normal force must balance the weight.

To find the player's initial velocity v_0, we will use kinematics. The time interval for the slide into second base is given as $t = 1.6$ s. Since the player comes to rest at the end of the slide, his final velocity is $v = 0$ m/s. The player's acceleration a can be obtained from Newton's second law, since the net force is the kinetic frictional force, which is known from part (a), and the mass is given. Since t, v, and a are known and we seek v_0, the appropriate kinematics equation is Equation 2.4 ($v = v_0 + at$).

SOLUTION

a. Since the normal force F_N balances the weight mg, we know that $F_N = mg$. Using this fact and Equation 4.8, we find that the magnitude of the kinetic frictional force is

$$f_k = \mu_k F_N = \mu_k mg = (0.49)(81 \text{ kg})\left(9.8 \text{ m/s}^2\right) = \boxed{390 \text{ N}}$$

b. Solving Equation 2.4 ($v = v_0 + at$) for v_0 gives $v_0 = v - at$. Taking the direction of the player's slide to be the positive direction, we use Newton's second law and Equation 4.8 for the kinetic frictional force to write the acceleration a as follows:

$$a = \frac{\Sigma F}{m} = \frac{-\mu_k mg}{m} = -\mu_k g$$

The acceleration is negative, because it points opposite to the player's velocity, since the player slows down during the slide. Thus, we find for the initial velocity that

$$v_0 = v - \left(-\mu_k g\right)t = 0 \text{ m/s} - \left[-(0.49)\left(9.8 \text{ m/s}^2\right)\right](1.6 \text{ s}) = \boxed{+7.7 \text{ m/s}}$$

---

48. ***REASONING AND SOLUTION*** The deceleration produced by the frictional force is

$$a = -\frac{f_k}{m} = \frac{-\mu_k mg}{m} = -\mu_k g$$

The speed of the automobile after 1.30 s have elapsed is given by Equation 2.4 as

$$v = v_0 + at = v_0 + \left(-\mu_k g\right)t = 16.1 \text{ m/s} - (0.720)\left(9.80 \text{ m/s}^2\right)(1.30 \text{ s}) = \boxed{6.9 \text{ m/s}}$$

---

49. $\boxed{\text{SSM}}$ ***REASONING*** Let us assume that the skater is moving horizontally along the $+x$ axis. The time t it takes for the skater to reduce her velocity to $v_x = +2.8$ m/s from $v_{0x} = +6.3$ m/s can be obtained from one of the equations of kinematics:

$$v_x = v_{0x} + a_x t \qquad (3.3a)$$

The initial and final velocities are known, but the acceleration is not. We can obtain the acceleration from Newton's second law $\left(\Sigma F_x = ma_x, \text{ Equation 4.2a}\right)$ in the following manner. The kinetic frictional force is the only horizontal force that acts on the skater, and, since it is a resistive force, it acts opposite to the direction of the motion. Thus, the net force in the x direction is $\Sigma F_x = -f_k$, where f_k is the magnitude of the kinetic frictional force. Therefore, the acceleration of the skater is $a_x = \Sigma F_x/m = -f_k/m$.

The magnitude of the frictional force is $f_k = \mu_k F_N$ (Equation 4.8), where μ_k is the coefficient of kinetic friction between the ice and the skate blades and F_N is the magnitude of the normal force. There are two vertical forces acting on the skater: the upward-acting normal force $\mathbf{F_N}$ and the downward pull of gravity (her weight) mg. Since the skater has no vertical acceleration, Newton's second law in the vertical direction gives (taking upward as the positive direction) $\Sigma F_y = F_N - mg = 0$. Therefore, the magnitude of the normal force is $F_N = mg$ and the magnitude of the acceleration is

$$a_x = \frac{-f_k}{m} = \frac{-\mu_k F_N}{m} = \frac{-\mu_k \cancel{m} g}{\cancel{m}} = -\mu_k g$$

SOLUTION

Solving the equation $v_x = v_{0x} + a_x t$ for the time and substituting the expression above for the acceleration yields

$$t = \frac{v_x - v_{0x}}{a_x} = \frac{v_x - v_{0x}}{-\mu_k g} = \frac{2.8 \text{ m/s} - 6.3 \text{ m/s}}{-(0.081)\left(9.80 \text{ m/s}^2\right)} = \boxed{4.4 \text{ s}}$$

52. ***REASONING AND SOLUTION*** Newton's second law applied in the vertical and horizontal directions gives

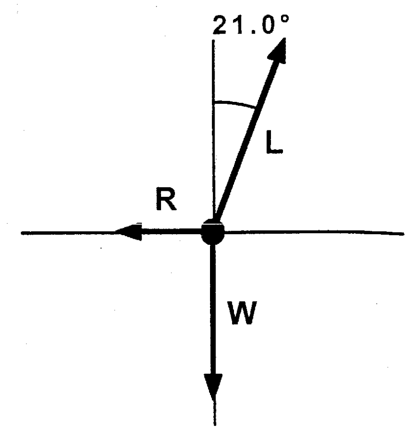
$$L \cos 21.0° - W = 0 \quad (1)$$
$$L \sin 21.0° - R = 0 \quad (2)$$

a. Equation (1) gives

$$L = \frac{W}{\cos 21.0°} = \frac{53\ 800\ \text{N}}{\cos 21.0°} = \boxed{57\ 600\ \text{N}}$$

b. Equation (2) gives

$$R = L \sin 21.0° = (57\ 600\ \text{N}) \sin 21.0° = \boxed{20\ 600\ \text{N}}$$



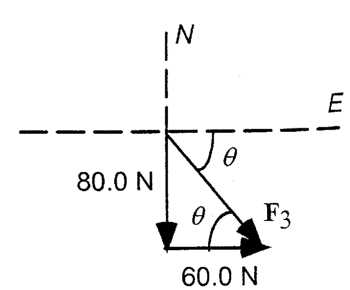
53. SSM ***REASONING*** In order for the object to move with constant velocity, the net force on the object must be zero. Therefore, the north/south component of the third force must be equal in magnitude and opposite in direction to the 80.0 N force, while the east/west component of the third force must be equal in magnitude and opposite in direction to the 60.0 N force. Therefore, the third force has components: 80.0 N due south and 60.0 N due east. We can use the Pythagorean theorem and trigonometry to find the magnitude and direction of this third force.

SOLUTION The magnitude of the third force is

$$F_3 = \sqrt{(80.0\ \text{N})^2 + (60.0\ \text{N})^2} = \boxed{1.00 \times 10^2\ \text{N}}$$

The direction of F_3 is specified by the angle θ where

$$\theta = \tan^{-1}\left(\frac{80.0\ \text{N}}{60.0\ \text{N}}\right) = \boxed{53.1°\text{, south of east}}$$



54. ***REASONING AND SOLUTION***
a. In the horizontal direction the thrust F is balanced by the resistive force f_r of the water. That is,

$$SF_x = 0$$

or

$$f_r = F = \boxed{7.40 \times 10^5\ \text{N}}$$

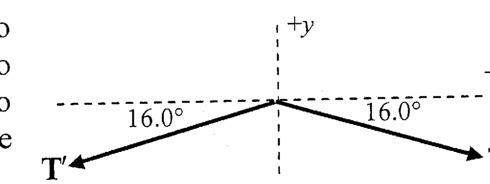
b. In the vertical direction, the weight, mg, is balanced by the buoyant force, F_b. So

$$SF_y = 0$$

gives

$$F_b = mg = (1.70 \times 10^8\ \text{kg})(9.80\ \text{m/s}^2) = \boxed{1.67 \times 10^9\ \text{N}}$$

55. ***REASONING*** The drawing shows the two forces, **T** and **T′**, that act on the tooth. To obtain the net force, we will add the two forces using the method of components (see Section 1.8).



SOLUTION The table lists the two vectors and their x and y components:

Vector	x component	y component
T	$+T \cos 16.0°$	$-T \sin 16.0°$
T′	$-T' \cos 16.0°$	$-T' \sin 16.0°$
T + T′	$+T \cos 16.0° - T' \cos 16.0°$	$-T \sin 16.0° - T' \sin 16.0°$

Since we are given that $T = T' = 21.0$ N, the sum of the x components of the forces is

$$\Sigma F_x = +T \cos 16.0° - T' \cos 16.0° = +(21\ \text{N}) \cos 16.0° - (21\ \text{N}) \cos 16.0° = 0\ \text{N}$$

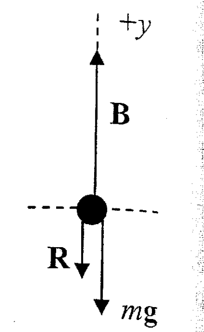
The sum of the y components is

$$\Sigma F_y = -T \sin 16.0° - T' \sin 16.0° = -(21\ \text{N}) \sin 16.0° - (21\ \text{N}) \sin 16.0° = -11.6\ \text{N}$$

The magnitude F of the net force exerted on the tooth is

$$F = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2} = \sqrt{(0\ \text{N})^2 + (-11.6\ \text{N})^2} = \boxed{11.6\ \text{N}}$$

70. ***REASONING*** In addition to the upward buoyant force **B** and the downward resistive force **R**, a downward gravitational force $m\mathbf{g}$ acts on the submarine (see the free-body diagram), where m denotes the mass of the submarine. Because the submarine is not in contact with any rigid surface, no normal force is exerted on it. We will calculate the acceleration of the submarine from Newton's second law, using the free-body diagram as a guide.



Free-body diagram of the submarine

SOLUTION Choosing up as the positive direction, we sum the forces acting on the submarine to find the net force S*F*. According to Newton's second law, the acceleration a is

$$a = \frac{\Sigma F}{m} = \frac{B - R - mg}{m} = \frac{16\ 140\ \text{N} - 1030\ \text{N} - (1450\ \text{kg})(9.80\ \text{m/s}^2)}{1450\ \text{kg}} = \boxed{+0.62\ \text{m/s}^2}$$

where the positive value indicates that the direction is upward.

---

71. ***REASONING*** According to Newton's second law, the acceleration has the same direction as the net force and a magnitude given by $a = \Sigma F/m$.

SOLUTION Since the two forces are perpendicular, the magnitude of the net force is given by the Pythagorean theorem as $\Sigma F = \sqrt{(40.0\ \text{N})^2 + (60.0\ \text{N})^2}$. Thus, according to Newton's second law, the magnitude of the acceleration is

$$a = \frac{\Sigma F}{m} = \frac{\sqrt{(40.0\ \text{N})^2 + (60.0\ \text{N})^2}}{4.00\ \text{kg}} = \boxed{18.0\ \text{m/s}^2}$$

The direction of the acceleration vector is given by

$$\theta = \tan^{-1}\left(\frac{60.0\ \text{N}}{40.0\ \text{N}}\right) = \boxed{56.3^\circ \text{ above the } +x \text{ axis}}$$

---

72. ***REASONING***

a. Since the fish is being pulled up at a constant speed, it has no acceleration. According to Newton's second law, the net force acting on the fish must be zero. We will use this fact to determine the weight of the heaviest fish that can be pulled up.

b. When the fish has an upward acceleration, we can still use Newton's second law to find the weight of the heaviest fish. However, because the fish has an acceleration, we will see that the maximum weight is less than that in part (a).

SOLUTION

a. There are two forces acting on the fish (taking the upward vertical direction to be the $+y$ direction): the maximum force of +45 N due to the line, and the weight $-W$ of the fish (negative, because the weight points down). Newton's second law $(\Sigma F_y = 0$, Equation 4.9b$)$ gives

$$\Sigma F_y = +45\ \text{N} - W = 0 \quad \text{or} \quad W = \boxed{45\ \text{N}}$$

b. Since the fish has an upward acceleration a_y, Newton's second law $(\Sigma F_y = ma_y$, Equation 4.2b$)$ becomes

$$\Sigma F_y = +45\ \text{N} - W' = ma_y$$

Where W' is the weight of the heaviest fish that can be pulled up with an acceleration. Solving this equation for W' gives

$$W' = +45\ \text{N} - ma_y$$

The mass m of the fish is the magnitude W' of its weight divided by the magnitude g of the acceleration due to gravity (see Equation 4.5), or $m = W'/g$. Substituting this relation for m into the previous equation gives

$$W' = +45\ \text{N} - \left(\frac{W'}{g}\right)a_y$$

Solving this equation for W' yields

$$W' = \frac{45\ \text{N}}{1 + \dfrac{a_y}{g}} = \frac{45\ \text{N}}{1 + \dfrac{2.0\ \text{m/s}^2}{9.80\ \text{m/s}^2}} = \boxed{37\ \text{N}}$$

---

73. $\boxed{\text{SSM}}$ ***REASONING*** If we assume that the acceleration is constant, we can use Equation 2.4 ($v = v_0 + at$) to find the acceleration of the car. Once the acceleration is known, Newton's second law ($\sum \mathbf{F} = m\mathbf{a}$) can be used to find the magnitude and direction of the net force that produces the deceleration of the car.

SOLUTION The average acceleration of the car is, according to Equation 2.4,

$$a = \frac{v - v_0}{t} = \frac{17.0\ \text{m/s} - 27.0\ \text{m/s}}{8.00\ \text{s}} = -1.25\ \text{m/s}^2$$

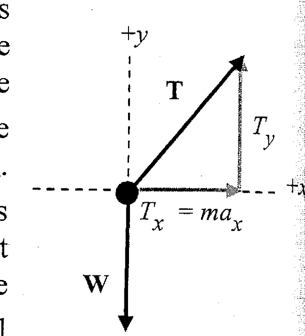
where the minus sign indicates that the direction of the acceleration is opposite to the direction of motion; therefore, the acceleration points due west.

According to Newton's Second law, the net force on the car is

$$\Sigma F = ma = (1380\text{ kg})(-1.25\text{ m/s}^2) = -1730\text{ N}$$

The magnitude of the net force is $\boxed{1730\text{ N}}$. From Newton's second law, we know that the direction of the force is the same as the direction of the acceleration, so the force also points $\boxed{\text{due west}}$.

74. ***REASONING*** In the absence of air resistance, the two forces acting on the sensor are its weight **W** and the tension **T** in the towing cable (see the free-body diagram). We see that T_x is the only horizontal force acting on the sensor, and therefore Newton's second law $SF_x = ma_x$ (Equation 4.2a) gives $T_x = ma_x$. Because the vertical component of the sensor's acceleration is zero, the vertical component of the cable's tension **T** must balance the sensor's weight: $T_y = W = mg$. We thus have sufficient information to calculate the horizontal and vertical components of the tension force **T**, and therefore to calculate its magnitude T from the Pythagorean theorem: $T^2 = T_x^2 + T_y^2$.



Free-body diagram of the sensor

SOLUTION Given that $T_x = ma_x$ and that $T_y = mg$, the Pythagorean theorem yields the magnitude T of the tension in the cable:

$$T = \sqrt{T_x^2 + T_y^2} = \sqrt{(ma)^2 + (mg)^2} = \sqrt{m^2a^2 + m^2g^2} = m\sqrt{a^2 + g^2}$$

$$= (129\text{ kg})\sqrt{\left(2.84\text{ m/s}^2\right)^2 + \left(9.80\text{ m/s}^2\right)^2} = \boxed{1320\text{ N}}$$

75. SSM ***REASONING AND SOLUTION***

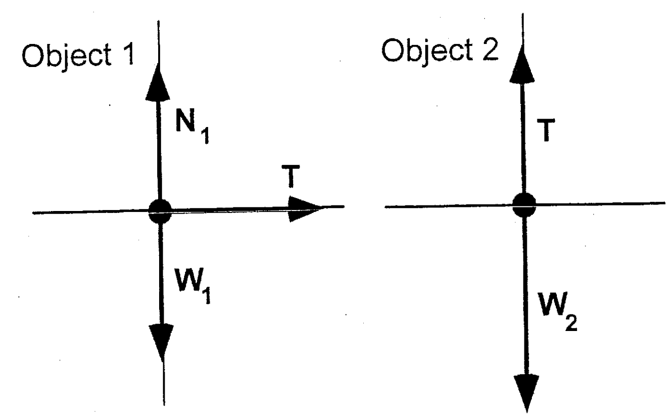
a. Each cart has the same mass and acceleration; therefore, the net force acting on any one of the carts is, according to Newton's second law

$$\Sigma F = ma = (26\text{ kg})(0.050\text{ m/s}^2) = \boxed{1.3\text{ N}}$$

b. The fifth cart must essentially push the sixth, seventh, eight, ninth and tenth cart. In other words, it must exert on the sixth cart a total force of

$$\Sigma F = ma = 5(26\text{ kg})(0.050\text{ m/s}^2) = \boxed{6.5\text{ N}}$$

76. ***REASONING AND SOLUTION*** Newton's second law applied to object 1 (422 N) gives



$$T = m_1 a_1$$

Similarly, for object 2 (185 N)

$$T - m_2 g = m_2 a_2$$

If the string is not to break or go slack, both objects must have accelerations of the same magnitude. Then $a_1 = a$ and $a_2 = -a$. The above equations become

$$T = m_1 a \qquad (1)$$
$$T - m_2 g = -m_2 a \qquad (2)$$

a. Substituting Equation (1) into Equation (2) and solving for a yields

$$a = \frac{m_2 g}{m_1 + m_2}$$

The masses of objects 1 and 2 are

$$m_1 = W_1/g = (422\text{ N})/\left(9.80\text{ m/s}^2\right) = 43.1\text{ kg}$$

$$m_2 = W_2/g = (185\text{ N})/\left(9.80\text{ m/s}^2\right) = 18.9\text{ kg}$$

The acceleration is

$$a = \frac{m_2 g}{m_1 + m_2} = \frac{(18.9\text{ kg})\left(9.80\text{ m/s}^2\right)}{43.1\text{ kg} + 18.9\text{ kg}} = \boxed{2.99\text{ m/s}^2}$$

b. Using this value in Equation (1) gives

$$T = m_1 a = (43.1\text{ kg})\left(2.99\text{ m/s}^2\right) = \boxed{129\text{ N}}$$

96. ***REASONING*** The magnitudes of the initial ($v_0 = 0$ m/s) and final ($v = 805$ m/s) velocities are known. In addition, data is given for the mass and the thrust, so that Newton's second law can be used to determine the acceleration of the probe. Therefore, kinematics Equation 2.4 ($v = v_0 + at$) can be used to determine the time t.

SOLUTION Solving Equation 2.4 for the time gives

$$t = \frac{v - v_0}{a}$$

Newton's second law gives the acceleration as $a = (\Sigma F)/m$. Using this expression in Equation 2.4 gives

$$t = \frac{(v - v_0)}{(\Sigma F)/m} = \frac{m(v - v_0)}{\Sigma F} = \frac{(474 \text{ kg})(805 \text{ m/s} - 0 \text{ m/s})}{56 \times 10^{-3} \text{ N}} = 6.8 \times 10^6 \text{ s}$$

Since one day contains 8.64×10^4 s, the time is

$$t = \left(6.8 \times 10^6 \cancel{\text{s}}\right) \frac{1 \text{ day}}{8.64 \times 10^4 \cancel{\text{s}}} = \boxed{79 \text{ days}}$$

---

97. SSM ***REASONING AND SOLUTION*** According to Equation 3.3b, the acceleration of the astronaut is $a_y = (v_y - v_{0y})/t = v_y/t$. The apparent weight and the true weight of the astronaut are related according to Equation 4.6. Direct substitution gives

$$\underbrace{F_N}_{\substack{\text{Apparent}\\\text{weight}}} = \underbrace{mg}_{\substack{\text{True}\\\text{weight}}} + ma_y = m\,(g + a_y) = m\left(g + \frac{v_y}{t}\right)$$

$$= (57 \text{ kg})\left(9.80 \text{ m/s}^2 + \frac{45 \text{ m/s}}{15 \text{ s}}\right) = \boxed{7.3 \times 10^2 \text{ N}}$$

---

98. ***REASONING*** According to Newton's second law ($\sum \mathbf{F} = m\mathbf{a}$), the acceleration of the object is given by $\mathbf{a} = \sum \mathbf{F}/m$, where $\sum \mathbf{F}$ is the net force that acts on the object. We must first find the net force that acts on the object, and then determine the acceleration using Newton's second law.

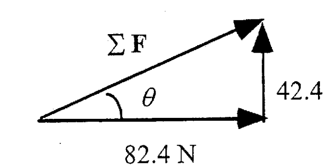
SOLUTION The following table gives the x and y components of the two forces that act on the object. The third row of that table gives the components of the net force.

Force	*x-Component*	*y-Component*
$\mathbf{F}_1$	40.0 N	0 N
$\mathbf{F}_2$	(60.0 N) cos 45.0° = 42.4 N	(60.0 N) sin 45.0° = 42.4 N
$\sum \mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2$	82.4 N	42.4 N

The magnitude of $\sum \mathbf{F}$ is given by the Pythagorean theorem as

$$\Sigma F = \sqrt{(82.4 \text{ N})^2 + (42.4)^2} = 92.7 \text{ N}$$

The angle θ that $\sum \mathbf{F}$ makes with the $+x$ axis is



$$\theta = \tan^{-1}\left(\frac{42.4 \text{ N}}{82.4 \text{ N}}\right) = 27.2°$$

According to Newton's second law, the magnitude of the acceleration of the object is

$$a = \frac{\sum F}{m} = \frac{92.7 \text{ N}}{3.00 \text{ kg}} = \boxed{30.9 \text{ m/s}^2}$$

Since Newton's second law is a vector equation, we know that the direction of the right hand side must be equal to the direction of the left hand side. In other words, the direction of the acceleration a is the same as the direction of the net force $\sum \mathbf{F}$. Therefore, the direction of the acceleration of the object is $\boxed{27.2° \text{ above the } +x \text{ axis}}$.

---

99. SSM ***REASONING*** In order to start the crate moving, an external agent must supply a force that is at least as large as the maximum value $f_s^{MAX} = \mu_s F_N$, where μ_s is the coefficient of static friction (see Equation 4.7). Once the crate is moving, the magnitude of the frictional force is very nearly constant at the value $f_k = \mu_k F_N$, where μ_k is the coefficient of kinetic friction (see Equation 4.8). In both cases described in the problem statement, there are only two vertical forces that act on the crate; they are the upward normal force F_N, and the downward pull of gravity (the weight) mg. Furthermore, the crate has no vertical acceleration in either case. Therefore, if we take upward as the positive direction, Newton's second law in the vertical direction gives $F_N - mg = 0$, and we see that, in both cases, the magnitude of the normal force is $F_N = mg$.

105. ***REASONING AND SOLUTION***

a. According to Equation 4.4, the weight of an object of mass m on the surface of Mars would be given by

$$W = \frac{GM_M m}{R_M^2}$$

where M_M is the mass of Mars and R_M is the radius of Mars. On the surface of Mars, the weight of the object can be given as $W = mg$ (see Equation 4.5), so

$$mg = \frac{GM_M m}{R_M^2} \quad \text{or} \quad g = \frac{GM_M}{R_M^2}$$

Substituting values, we have

$$g = \frac{(6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2)(6.46\times10^{23}\ \text{kg})}{(3.39\times10^6\ \text{m})^2} = \boxed{3.75\ \text{m/s}^2}$$

b. According to Equation 4.5,

$$W = mg = (65\ \text{kg})(3.75\ \text{m/s}^2) = \boxed{2.4\times10^2\ \text{N}}$$

106. ***REASONING*** Each particle experiences two gravitational forces, one due to each of the remaining particles. To get the net gravitational force, we must add the two contributions, taking into account the directions. The magnitude of the gravitational force that any one particle exerts on another is given by Newton's law of gravitation as $F = Gm_1m_2/r^2$. Thus, for particle A, we need to apply this law to its interaction with particle B and with particle C. For particle B, we need to apply the law to its interaction with particle A and with particle C. Lastly, for particle C, we must apply the law to its interaction with particle A and with particle B. In considering the directions, we remember that the gravitational force between two particles is always a force of attraction.

SOLUTION We begin by calculating the magnitude of the gravitational force for each pair of particles:

$$F_{AB} = \frac{Gm_Am_B}{r^2} = \frac{\left(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)(363\ \text{kg})(517\ \text{kg})}{(0.500\ \text{m})^2} = 5.007\times10^{-5}\ \text{N}$$

$$F_{BC} = \frac{Gm_Bm_C}{r^2} = \frac{\left(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)(517\ \text{kg})(154\ \text{kg})}{(0.500\ \text{m})^2} = 8.497\times10^{-5}\ \text{N}$$

$$F_{AC} = \frac{Gm_Am_C}{r^2} = \frac{\left(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)(363\ \text{kg})(154\ \text{kg})}{(0.500\ \text{m})^2} = 6.629\times10^{-6}\ \text{N}$$

In using these magnitudes we take the direction to the right as positive.

a. Both particles B and C attract particle A to the right, the net force being

$$F_A = F_{AB} + F_{AC} = 5.007\times10^{-5}\ \text{N} + 6.629\times10^{-6}\ \text{N} = \boxed{5.67\times10^{-5}\ \text{N, right}}$$

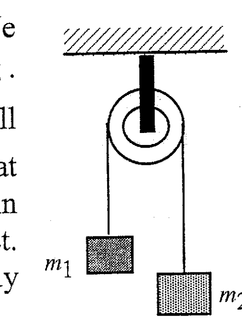
b. Particle C attracts particle B to the right, while particle A attracts particle B to the left, the net force being

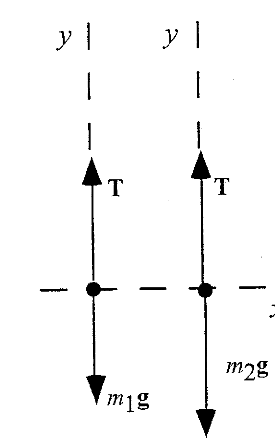
$$F_B = F_{BC} - F_{AB} = 8.497\times10^{-5}\ \text{N} - 5.007\times10^{-5}\ \text{N} = \boxed{3.49\times10^{-5}\ \text{N, right}}$$

c. Both particles A and B attract particle C to the left, the net force being

$$F_C = F_{AC} + F_{BC} = 6.629\times10^{-6}\ \text{N} + 8.497\times10^{-5}\ \text{N} = \boxed{9.16\times10^{-5}\ \text{N, left}}$$

107. SSM ***REASONING AND SOLUTION*** The system is shown in the drawing. We will let $m_1 = 21.0$ kg, and $m_2 = 45.0$ kg. Then, m_1 will move upward, and m_2 will move downward. There are two forces that act on each object; they are the tension T in the cord and the weight mg of the object. The forces are shown in the free-body diagrams at the far right.





We will take up as the positive direction. If the acceleration of m_1 is a, then the acceleration of m_2 must be $-a$.

From Newton's second law, we have for m_1

$$\sum F_y = T - m_1 g = m_1 a \qquad (1)$$

and for m_2

$$\sum F_y = T - m_2 g = -m_2 a \qquad (2)$$

a. Eliminating T between these two equations, we obtain

$$a = \frac{m_2 - m_1}{m_2 + m_1} g = \left(\frac{45.0\text{ kg} - 21.0\text{ kg}}{45.0\text{ kg} + 21.0\text{ kg}}\right)(9.80\text{ m/s}^2) = \boxed{3.56\text{ m/s}^2}$$

b. Eliminating a between Equations (1) and (2), we find

$$T = \frac{2m_1 m_2}{m_1 + m_2} g = \left[\frac{2(21.0\text{ kg})(45.0\text{ kg})}{21.0\text{ kg} + 45.0\text{ kg}}\right](9.80\text{ m/s}^2) = \boxed{281\text{ N}}$$

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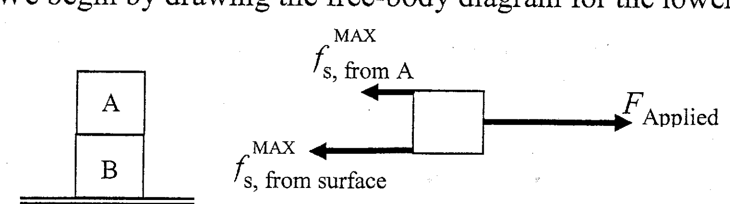
108. ***REASONING*** Static friction determines the magnitude of the applied force at which either the upper or lower block begins to slide. For the upper block the static frictional force is applied only by the lower block. For the lower block, however, separate static frictional forces are applied by the upper block and by the horizontal surface. The maximum magnitude of any of the individual frictional forces is given by Equation 4.7 as the coefficient of static friction times the magnitude of the normal force.

SOLUTION We begin by drawing the free-body diagram for the lower block.



Free-body diagram for lower block B

This diagram shows that three horizontal forces act on the lower block, the applied force, and the two maximum static frictional forces, one from the upper block and one from the horizontal surface. At the instant that the lower block just begins to slide, the blocks are in equilibrium and the applied force is balanced by the two frictional forces, with the result that

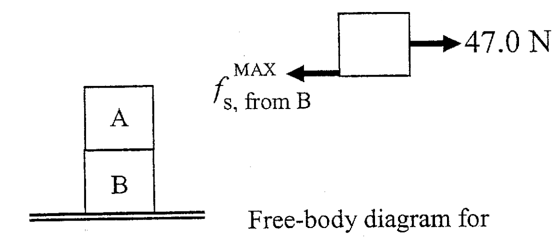
$$F_{\text{Applied}} = f_{\text{s, from A}}^{\text{MAX}} + f_{\text{s, from surface}}^{\text{MAX}} \qquad (1)$$

According to Equation 4.7, the magnitude of the maximum frictional force from the surface is

$$f_{\text{s, from surface}}^{\text{MAX}} = \mu_s F_N = \mu_s 2mg \qquad (2)$$

Here, we have recognized that the normal force F_N from the horizontal surface must balance the weight $2mg$ of both blocks.

It remains now to determine the magnitude of the maximum frictional force $f_{\text{s, from A}}^{\text{MAX}}$ from the upper block. To this end, we draw the free-body diagram for the upper block at the instant that it just begins to slip due to the 47.0-N applied force. At this instant the block is in equilibrium, so that the frictional force from the lower block B balances the 47.0-N force. Thus, $f_{\text{s, from B}}^{\text{MAX}} = 47.0\text{ N}$, and according to Equation 4.7, we have



Free-body diagram for upper block A

$$f_{\text{s, from B}}^{\text{MAX}} = \mu_s F_N = \mu_s mg = 47.0\text{ N}$$

Here, we have recognized that the normal force F_N from the lower block must balance the weight mg of only the upper block. This result tells us that $\mu_s mg = 47.0$ N. To determine $f_{\text{s, from A}}^{\text{MAX}}$ we invoke Newton's third law to conclude that the magnitudes of the frictional forces at the A-B interface are equal, since they are action-reaction forces. Thus, $f_{\text{s, from A}}^{\text{MAX}} = \mu_s mg$. Substituting this result and Equation (2) into Equation (1) gives

$$F_{\text{Applied}} = f_{\text{s, from A}}^{\text{MAX}} + f_{\text{s, from surface}}^{\text{MAX}} = \mu_s mg + \mu_s 2mg = 3(47.0\text{ N}) = \boxed{141\text{ N}}$$

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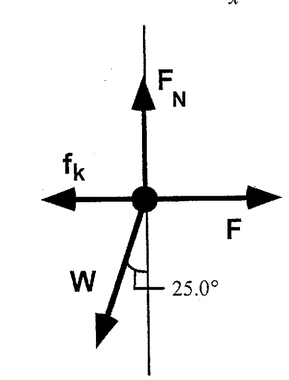
109. ***REASONING AND SOLUTION*** If the $+x$ axis is taken in the direction of motion, $\mathrm{S}F_x = 0$ gives



$$F - f_k - mg\sin\theta = 0$$

where

$$f_k = \mu_k F_N$$

Then

$$F - \mu_k F_N - mg\sin\theta = 0 \qquad (1)$$

Also, $\mathrm{S}F_y = 0$ gives

$$F_N - mg\cos\theta = 0$$

so

$$F_N = mg\cos\theta \qquad (2)$$

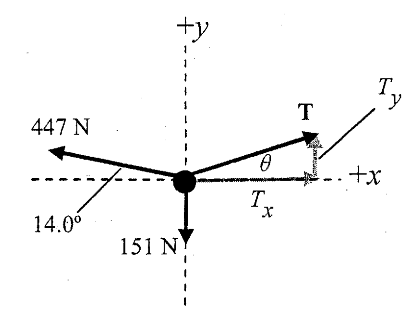
Substituting Equation (2) into Equation (1) and solving for F yields

$$F = mg(\sin\theta + \mu_k \cos\theta)$$

$$F = (55.0\text{ kg})(9.80\text{ m/s}^2)[\sin 25.0° + (0.120)\cos 25.0°] = \boxed{286\text{ N}}$$

110. ***REASONING*** Since the wire beneath the limb is at rest, it is in equilibrium and the net force acting on it must be zero. Three forces comprise the net force, the 151-N force from the limb, the 447-N tension force from the left section of the wire, and the tension force **T** from the right section of the wire. We will resolve the forces into components and set the sum of the x components and the sum of the y components separately equal to zero. In so doing we will obtain two equations containing the unknown quantities, which are the horizontal and vertical components of the tension force **T**. These two equations will be solved simultaneously to give values for the two unknowns. Knowing the components of the tension force, we can determine its magnitude and direction.

SOLUTION Let T_x and T_y be the horizontal and vertical components of the tension force. The free-body diagram for the wire beneath the limb is as follows:



Taking upward and to the right as the positive directions, we find for the x components of the forces that

$$\Sigma F_x = T_x - (447\text{ N})\cos 14.0° = 0$$

$$T_x = (447\text{ N})\cos 14.0° = 434\text{ N}$$

For the y components of the forces we have

$$\Sigma F_y = T_y + (447\text{ N})\sin 14.0° - 151\text{ N} = 0$$

$$T_y = -(447\text{ N})\sin 14.0° + 151\text{ N} = 43\text{ N}$$

The magnitude of the tension force is

$$T = \sqrt{T_x^2 + T_y^2} = \sqrt{(434\text{ N})^2 + (43\text{ N})^2} = \boxed{436\text{ N}}$$

Since the components of the tension force and the angle θ are related by $\tan\theta = T_y / T_x$, we find that

$$\theta = \tan^{-1}\left(\frac{T_y}{T_x}\right) = \tan^{-1}\left(\frac{43\text{ N}}{434\text{ N}}\right) = \boxed{5.7°}$$

111. SSM ***REASONING*** The shortest time to pull the person from the cave corresponds to the maximum acceleration, a_y, that the rope can withstand. We first determine this acceleration and then use kinematic Equation 3.5b ($y = v_{0y}t + \frac{1}{2}a_y t^2$) to find the time t.

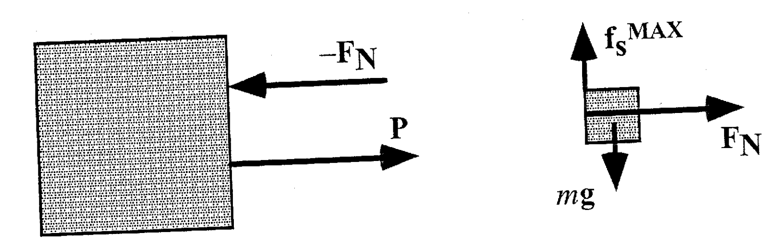
SOLUTION As the person is being pulled from the cave, there are two forces that act on him; they are the tension T in the rope that points vertically upward, and the weight of the person mg that points vertically downward. Thus, if we take upward as the positive direction, Newton's second law gives $\Sigma F_y = T - mg = ma_y$. Solving for a_y, we have

$$a_y = \frac{T}{m} - g = \frac{T}{W/g} - g = \frac{569\text{ N}}{(5.20\times10^2\text{ N})/(9.80\text{ m/s}^2)} - 9.80\text{ m/s}^2 = 0.92\text{ m/s}^2$$

Therefore, from Equation 3.5b with $v_{0y} = 0$ m/s, we have $y = \frac{1}{2}a_y t^2$. Solving for t, we find

$$t = \sqrt{\frac{2y}{a_y}} = \sqrt{\frac{2(35.1\text{ m})}{0.92\text{ m/s}^2}} = \boxed{8.7\text{ s}}$$

112. ***REASONING*** The free-body diagrams for the large cube (mass = M) and the small cube (mass = m) are shown in the following drawings. In the case of the large cube, we have omitted the weight and the normal force from the surface, since the play no role in the solution (although they do balance).



In these diagrams, note that the two blocks exert a normal force on each other; the large block exerts the force F_N on the smaller block, while the smaller block exerts the force $-F_N$ on the larger block. In accord with Newton's third law these forces have opposite directions and equal magnitudes F_N. Under the influence of the forces shown, the two blocks have the same acceleration a. We begin our solution by applying Newton's second law to each one.

SOLUTION According to Newton's second law, we have

$$\underbrace{\Sigma F = P - F_N = Ma}_{\text{Large block}} \qquad \underbrace{F_N = ma}_{\text{Small block}}$$