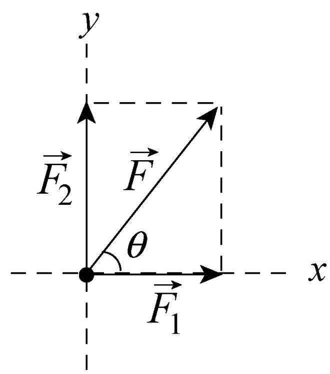
1. (a) The free-body diagram depicted for the body is shown to the right. The forces are



$$\vec{F}_1 = 9.0 \text{ N and } \vec{F}_2 = 7.0 \text{ N}$$

The resultant force is

$$\vec{F} = \sqrt{(9.0 \text{ N})^2 + (7.0 \text{ N})^2} = \sqrt{81 \text{ N} + 49 \text{ N}}$$
$$= \sqrt{130} \text{ N} = 11.4 \text{ N}$$

Using the equation $\vec{a} = \frac{\vec{F}}{m}$, we get the magnitude of the acceleration of the body as

$$a = \frac{\vec{F}}{m} = \frac{11.4 \text{ N}}{6.0 \text{ kg}} = 1.9 \text{ m/s}^2.$$

(b) From the figure, the direction of the acceleration of the body is calculated as follows:

$$\tan\theta = \frac{F_2}{F_1} = \frac{7.0\,\text{N}}{9.0\,\text{N}} \approx 0.77\,\text{N} \qquad \Rightarrow \qquad \theta = 38°,$$

from which we conclude that the direction of the acceleration of the body is $38°$ counter-clockwise from the positive x direction.

2. We apply Newton's second law (Eq. 5-1 or, equivalently, Eq. 5-2). The net force applied on the chopping block is $\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2$, where the vector addition is done using unit-vector notation. The acceleration of the block is given by $\vec{a} = \left(\vec{F}_1 + \vec{F}_2\right) / m$.

(a) In the first case

$$\vec{F}_1 + \vec{F}_2 = \left[(3.0\,\text{N})\hat{\text{i}} + (4.0\,\text{N})\hat{\text{j}}\right] + \left[(-3.0\,\text{N})\hat{\text{i}} + (-4.0\,\text{N})\hat{\text{j}}\right] = 0$$

so $\vec{a} = 0$.

(b) In the second case, the acceleration $\vec{a}$ equals

$$\frac{\vec{F}_1 + \vec{F}_2}{m} = \frac{\left((3.0\,\text{N})\hat{\text{i}} + (4.0\,\text{N})\hat{\text{j}}\right) + \left((-3.0\,\text{N})\hat{\text{i}} + (4.0\,\text{N})\hat{\text{j}}\right)}{2.5\,\text{kg}} = (3.2\,\text{m/s}^2)\hat{\text{j}}.$$

(c) In this final situation, $\vec{a}$ is

$$\frac{\vec{F}_1 + \vec{F}_2}{m} = \frac{\left((3.0\,\text{N})\hat{\text{i}} + (4.0\,\text{N})\hat{\text{j}}\right) + \left((3.0\,\text{N})\hat{\text{i}} + (-4.0\,\text{N})\hat{\text{j}}\right)}{2.5\,\text{kg}} = (2.4\,\text{m/s}^2)\hat{\text{i}}.$$

3. According to Newtonôs second law of motion, the net force $\vec{F}_{\text{net}}$ force on a body of mass m is related to the bodyôs acceleration by

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

Using the above relation, we get the net force of the body as

$$\vec{F}_{\text{net}} = m\vec{a} = 2.00\,\text{kg} \times 3.00\,\text{m/s}^2 = 6.00\,\text{N}.$$

(a) The x component of the force is

$$F_x = ma_x = ma\cos 20.0° = (2.00\,\text{kg})\,(3.00\,\text{m/s}^2)\cos 30.0°$$

$$= \frac{6\sqrt{3}}{2} = 3\sqrt{3} = 5.196\,\text{N} = 5.20\,\text{N}.$$

(b) The y component of the force is

$$F_y = ma_y = ma\sin 20.0° = (2.00\,\text{kg})\,(3.00\,\text{m/s}^2)\sin 30.0°$$

$$= 6.00 \times \frac{1}{2} = 3.00\,\text{N}.$$

(c) In unit-vector notation, the force vector is

$$\vec{F} = F_x\hat{i} + F_y\hat{j} = (5.20\text{ N})\hat{i} + (3.00\text{ N})\hat{j}.$$

4. As the body is moving with a constant velocity (i.e., $\vec{v}$ = constant), the net force acting on the body is zero and therefore the acceleration of the body is also zero (i.e., $\vec{a}$ = 0), that is,

$$\begin{aligned} \vec{F}_{\text{net}} &= \vec{F}_1 + \vec{F}_2 = m\vec{a} = 0 \\ &= (2\ \text{N})\hat{i} - (5\ \text{N})\hat{j} + (x\,\text{N})\hat{i} + (y\ \text{N})\hat{j} \end{aligned}$$

Hence, the other force is

$$\vec{F}_2 = -\vec{F}_1 = (-2\ \text{N})\,\hat{i} + (5\ \text{N})\,\hat{j}.$$

5. The net force applied on the chopping block is

$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 ,$$

where the vector addition is done using unit-vector notation. The acceleration of the block is given by

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m} = \frac{\vec{F}_1 + \vec{F}_2 + \vec{F}_3}{m}$$

(a) The forces exerted by the three astronauts can be expressed in unit-vector notation as follows:

$$\begin{aligned}
\vec{F}_1 &= (32\text{ N})\left(\cos 30^\circ\,\hat{\text{i}} + \sin 30^\circ\,\hat{\text{j}}\right) = (27.7\text{ N})\,\hat{\text{i}} + (16\text{ N})\,\hat{\text{j}} \\
\vec{F}_2 &= (55\text{ N})\left(\cos 0^\circ\,\hat{\text{i}} + \sin 0^\circ\,\hat{\text{j}}\right) = (55\text{ N})\,\hat{\text{i}} \\
\vec{F}_3 &= (41\text{ N})\left(\cos(-60^\circ)\,\hat{\text{i}} + \sin(-60^\circ)\,\hat{\text{j}}\right) = (20.5\text{ N})\,\hat{\text{i}} - (35.5\text{ N})\,\hat{\text{j}}.
\end{aligned}$$

The resultant acceleration of the asteroid of mass m = 120 kg is therefore

$$\vec{a} = \frac{\left(27.7\,\hat{\text{i}} + 16\,\hat{\text{j}}\right)\text{N} + \left(55\,\hat{\text{i}}\right)\text{N} + \left(20.5\,\hat{\text{i}} - 35.5\,\hat{\text{j}}\right)\text{N}}{120\text{ kg}} = (0.86\text{ m/s}^2)\,\hat{\text{i}} - (0.16\text{ m/s}^2)\,\hat{\text{j}}.$$

(b) The magnitude of the acceleration vector is

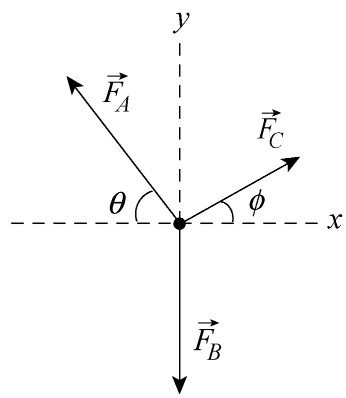
$$|\vec{a}| = \sqrt{a_x^2 + a_y^2} = \sqrt{(0.86\text{ m/s}^2)^2 + \left(-0.16\text{ m/s}^2\right)^2} = 0.88\text{ m/s}^2 .$$

(c) The vector $\vec{a}$ makes an angle θ with the $+x$ axis, where

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{-0.16\text{ m/s}^2}{0.86\text{ m/s}^2}\right) = -11^\circ .$$

6. Since the tire remains stationary, by Newton's second law, the net force must be zero:

$$\vec{F}_{\text{net}} = \vec{F}_A + \vec{F}_B + \vec{F}_C = m\vec{a} = 0.$$



From the free-body diagram shown on the right, we have

$$0 = \sum F_{\text{net},x} = F_C \cos\phi - F_A \cos\theta$$
$$0 = \sum F_{\text{net},y} = F_A \sin\theta + F_C \sin\phi - F_B$$

To solve for F_B, we first compute ϕ.

With $F_A = 230$ N, $F_C = 170$ N, and $\theta = 47°$, we get

$$\cos\phi = \frac{F_A \cos\theta}{F_C} = \frac{(230\text{ N})\cos 47.0°}{170\text{ N}} = 0.923 \quad \Rightarrow \phi = 22.7°$$

Substituting the value into the second force equation, we find

$$F_B = F_A \sin\theta + F_C \sin\phi = (230\text{ N})\sin 47.0° + (170\text{ N})\sin 22.7 = 234\text{ N}.$$

7. **THINK** A box is under acceleration by two applied forces. We use Newtonôs second law to solve for the unknown second force.

EXPRESS We denote the two forces as $\vec{F}_1$ and $\vec{F}_2$. According to Newtonôs second law, $\vec{F}_1 + \vec{F}_2 = m\vec{a}$, so the second force is $\vec{F}_2 = m\vec{a} - \vec{F}_1$. Note that since the acceleration is in the third quadrant, we expect $\vec{F}_2$ to be in the third quadrant as well.

ANALYZE

(a) In unit vector notation $\vec{F}_1 = (20.0\text{ N})\hat{\mathrm{i}}$ and

$$\vec{a} = -(12.0\sin 30.0°\,\text{m/s}^2)\hat{\mathrm{i}} - (12.0\cos 30.0°\,\text{m/s}^2)\hat{\mathrm{j}} = -(6.00\text{ m/s}^2)\hat{\mathrm{i}} - (10.4\text{ m/s}^2)\hat{\mathrm{j}}.$$

Therefore, we find the second force to be

$$\begin{aligned}\vec{F}_2 &= m\vec{a} - \vec{F}_1 \\ &= (2.00\text{ kg})(-6.00\text{ m/s}^2)\hat{\mathrm{i}} + (2.00\text{ kg})(-10.4\text{ m/s}^2)\hat{\mathrm{j}} - (20.0\text{ N})\hat{\mathrm{i}} \\ &= (-32.0\text{ N})\hat{\mathrm{i}} - (20.8\text{ N})\hat{\mathrm{j}}.\end{aligned}$$

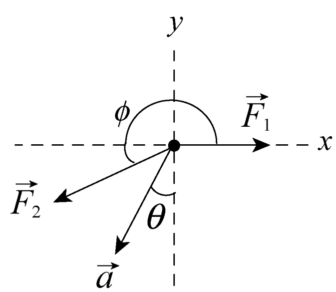
(b) The magnitude of $\vec{F}_2$ is $|\vec{F}_2| = \sqrt{F_{2x}^2 + F_{2y}^2} = \sqrt{(-32.0\text{ N})^2 + (-20.8\text{ N})^2} = 38.2\text{ N}.$

(c) The angle that $\vec{F}_2$ makes with the positive x-axis is found from

$$\tan\phi = \left(\frac{F_{2y}}{F_{2x}}\right) = \frac{-20.8\text{ N}}{-32.0\text{ N}} = 0.656.$$

Consequently, the angle is either 33.0° or 33.0° + 180° = 213°. Since both the x and y components are negative, the correct result is ϕ = 213° from the +x-axis. An alternative answer is $213° - 360° = -147°$.

LEARN The result is shown in the figure on the right. The calculation confirms our expectation that $\vec{F}_2$ lies in the third quadrant (same as $\vec{a}$). The net force is



$$\begin{aligned}\vec{F}_{\text{net}} &= \vec{F}_1 + \vec{F}_2 = (20.0\text{ N})\hat{\mathrm{i}} + \left[(-32.0\text{ N})\hat{\mathrm{i}} - (20.8\text{ N})\hat{\mathrm{j}}\right] \\ &= (-12.0\text{ N})\hat{\mathrm{i}} - (20.8\text{ N})\hat{\mathrm{j}}\end{aligned}$$

which points in the same direction as $\vec{a}$.

8. We note that

$$\vec{F}_{\text{net}} = m\vec{a} = (1.50\text{ kg})\left[(-8.00\text{ m/s}^2)\hat{\text{i}} + (6.00\text{ m/s}^2)\hat{\text{j}}\right] = (-12.0\text{ N})\,\hat{\text{i}} + (9.0\text{ N})\,\hat{\text{j}}.$$

With the other forces as specified in the problem, then Newton's second law gives the third force as

$$\vec{F}_3 = m\vec{a} - \vec{F}_1 - \vec{F}_2 = (-30\text{ N})\,\hat{\text{i}} - (15\text{ N})\,\hat{\text{j}}.$$

9. Here, we note that acceleration is the second time derivative of the position function; it is a vector and can be determined from its components. The net force is related to the acceleration according to Newton's second law of motion. Therefore, differentiating $x(t) = -16.0 + 3.0t + 5.0t^3$ twice with respect to t, we get

$$\frac{dx}{dt} = 0.00 + 3.00 - 15.0t^2$$
$$\frac{d^2x}{dt^2} = -30.0t$$

Similarly, differentiating $y(t) = 26.0 + 8.00t - 10.0t^2$ twice with respect to t, we get

$$\frac{dy}{dt} = 0.00 + 8.00 - 20.0t$$
$$\frac{d^2y}{dt^2} = -20.0$$

(a) We find the acceleration as follows:

$$\vec{a} = a_x\hat{i} + a_y\hat{j} = \left(\frac{d^2x}{dt^2}\right)\hat{i} + \left(\frac{d^2y}{dt^2}\right)\hat{j} = (-30.0t)\hat{i} + (-20.0)\hat{j}.$$

At $t = 0.80\text{ s}$, we have $\vec{a} = (-24.0\text{ m/s}^2)\hat{i} + (-20.0\text{ m/s}^2)\hat{j}$ with a magnitude of

$$a = |\,\vec{a}\,| = \sqrt{(-24.0\text{ m/s}^2)^2 + (-20.0\text{ m/s}^2)^2} = 31.24\text{ m/s}^2 \approx 31\text{ m/s}^2.$$

Thus, the magnitude of the force is $F = ma = (0.45\text{ kg})(31.24\text{ m/s}^2) = 14.1\text{ N}$.

(b) To find the angle that $\vec{F}$ or $\vec{a} = \vec{F}/m$ makes with $+x$, we calculate

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{-20.0\text{ m/s}^2}{-12.0\text{ m/s}^2}\right) = 39.8° \text{ or } -140.2°.$$

From the components we know that the force and acceleration vectors are in the third quadrant. So, we choose –140°, rounded to three significant digits.

(c) The direction of travel is the direction of a tangent to the path, which is the direction of the velocity vector:

$$\vec{v}(t) = v_x\hat{i} + v_y\hat{j} = \left(\frac{dx}{dt}\right)\hat{i} + \left(\frac{dy}{dt}\right)\hat{j} = (3.00 - 15.0t^2)\hat{i} + (8.00 - 20.0t)\hat{j}.$$

At $t = 0.80$ s, we have $\vec{v}(t = 0.80\text{ s}) = (-6.60\text{ m/s})\hat{\imath} + (-8.00\text{ m/s})\hat{\jmath}$. Therefore, the angle $\vec{v}$ makes with $+x$ is

$$\theta_v = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{-8.00\text{ m/s}}{-6.60\text{ m/s}}\right) = 50.4° \text{ or } -129.6°.$$

Because $\vec{v}$ is in the third quadrant, we choose the angle of the objectős travel direction as ï 130°, rounded to three significant digits.

10. To solve the problem, we note that acceleration is the second time derivative of the position function, and the net force is related to the acceleration via Newton's second law. Thus, differentiating

$$x(t) = -13.00 + 2.00t + 4.00t^2 - 3.00t^3$$

twice with respect to t, we get

$$\frac{dx}{dt} = 2.00 + 8.00t - 9.00t^2, \quad \frac{d^2x}{dt^2} = 8.00 - 18.0t$$

The net force acting on the particle at $t = 2.60\text{ s}$ is

$$\vec{F} = m\frac{d^2x}{dt^2}\hat{\mathrm{i}} = (0.150)\left[8.00 - 18.0(2.60)\right]\hat{\mathrm{i}} = (-5.82\text{ N})\hat{\mathrm{i}}$$

11. We have

$$x = 4.0\,\text{m} + (5.0\,\text{m/s})t + kt^2 - (3.0\,\text{m/s}^2)t^3$$

Therefore,

$$v_x = \frac{dx}{dt} = 0.0 + 5.0 + 2.0kt^2 - 9.0t^3$$
$$a_x = \frac{d^2x}{dt^2} = 2.0k - 18t$$

Force is given by

$$F = ma_x\,.$$

Substituting the values in this relation, we get

$$-37 = 3.0(2.0k - 18t)$$
$$-\frac{37}{3.0} = 2.0k - 72 \Rightarrow -\frac{37}{3.0} + 72 = 2.0k$$

Therefore,

$$k = \frac{-37}{6} + \frac{72}{2} = -6.16 + 36 \approx 30\ \text{m/s}^2.$$

12. From the slope of the graph we find $a_x = 3.0$ m/s^2. Applying Newtonôs second law to the x axis (and taking θ to be the angle between F_1 and F_2), we have

$$F_1 + F_2\cos\theta = m\,a_x \quad \Rightarrow \quad \theta = 56°.$$

13. For the mass $3m$, we have

$$3mg - 2T = 3ma_3 \tag{1}$$

For the mass $2m$, we have

$$T - 0 = 2ma_1 \tag{2}$$

For the mass m, we have

$$T - 0 = ma_2 \tag{3}$$

From Eqs. (2) and (3), we get

$$a_2 = 2a_1$$

If the string of $2m$ mass moves by a distance x, the string of mass m moves by distance $2x$. The total distance $3x$ is shared equally on both sides of the pulley and the mass $3m$ comes down by

$$\frac{3x}{2} = 1.5x \qquad \left[\text{from the equation of motion,} (x - x_0) = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2\right]$$

$$a_3 = 1.5a_1$$

Adding Eqs. (2) and (3), we get

$$\begin{aligned} T + T &= 2ma_1 + ma_2 \\ &= 2ma_1 + m2a_1 \end{aligned}$$

That is,

$$2T = 4ma_1 \tag{4}$$

From Eq. (1), we get

$$\begin{aligned} 3mg - 4ma_1 &= 3m \times 1.5a_1 \\ 3mg &= 8.5ma_1 \\ a_1 &= \left(\frac{3}{8.5}\right)g \\ a_3 &= 1.5a_1 \\ a_3 &= \left(\frac{3 \times 1.5}{8.5}\right)g = \left(\frac{4.5}{8.5}\right)g = 0.53g = 5.2 \text{ m/s}^2. \end{aligned}$$

14. Three vertical forces are acting on the block: the earth pulls down on the block with gravitational force 4.0 N; a spring pulls up on the block with elastic force 1.0 N; and, the surface pushes up on the block with normal force F_N. There is no acceleration, so

$$0 = F_N + 1.0 \text{ N} - 4.0 \text{ N}$$

yields F_N = 3.0 N.

(a) By Newtonôs third law, the force exerted by the block on the surface has that same magnitude but opposite direction: 3.0 N.

(b) The direction is down.

15. **THINK** We have a piece of salami hung to a spring scale in various ways. The problem is to explore the concept of weight.

EXPRESS We first note that the reading on the spring scale is proportional to the weight of the salami. In all three cases (a) ï (c) depicted in Fig. 5-34, the scale is not accelerating, which means that the two cords exert forces of equal magnitude on it. The scale reads the magnitude of either of these forces. In each case the tension force of the cord attached to the salami must be the same in magnitude as the weight of the salami because the salami is not accelerating. Thus the scale reading is mg, where m is the mass of the salami.

ANALYZE In all three cases (a) ï (c), the reading on the scale is

$$w = mg = (11.0 \text{ kg})(9.8 \text{ m/s}^2) = 108 \text{ N}.$$

LEARN The weight of an object is measured when the object is not accelerating vertically relative to the ground. If it is, then the weight measured is called the apparent weight.

16. (a) There are six legs, and the vertical component of the tension force in each leg is $T\sin\theta$ where $\theta = 40°$. For vertical equilibrium (zero acceleration in the y direction) then Newtonôs second law leads to

$$6T\sin\theta = mg \Rightarrow T = \frac{mg}{6\sin\theta}$$

which (expressed as a multiple of the bugôs weight mg) gives roughly $T/mg \approx 0.26$ 0.

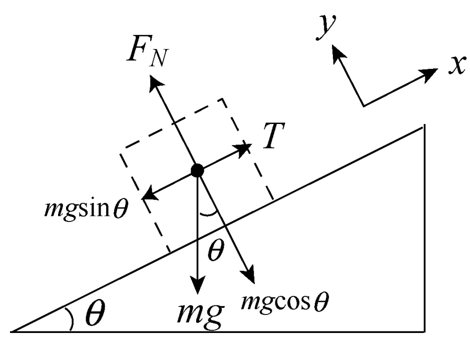
(b) The angle θ is measured from horizontal, so as the insect ñstraightens out the legsò θ will increase (getting closer to $90°$), which causes $\sin\theta$ to increase (getting closer to 1) and consequently (since $\sin\theta$ is in the denominator) causes T to decrease.

17. **THINK** A block attached to a cord is resting on an incline plane. We apply Newtonõs second law to solve for the tension in the cord and the normal force on the block.

EXPRESS The free-body diagram of the problem is shown to the right. Since the acceleration of the block is zero, the components of Newtonõs second law equation yield

$$T \text{ ï } mg\sin\theta = 0$$
$$F_N \text{ ï } mg\cos\theta = 0,$$

where T is the tension in the cord, and F_N is the normal force on the block.



ANALYZE

(a) Solving the first equation for the tension in the string, we find

$$T = mg\sin\theta = (8.5\text{ kg})(9.8\text{ m/s}^2)\sin 30° = 42\text{ N}.$$

(b) We solve the second equation above for the normal force F_N:

$$F_N = mg\cos\theta = (8.5\text{ kg})(9.8\text{ m/s}^2)\cos 30° = 72\text{ N}.$$

(c) When the cord is cut, it no longer exerts a force on the block and the block accelerates. The x component of the second law becomes ï$mg\sin\theta = ma$, so the acceleration becomes

$$a = -g\sin\theta = -(9.8\text{ m/s}^2)\sin 30° = -4.9\text{ m/s}^2.$$

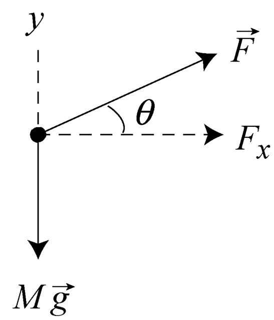
The negative sign indicates the acceleration is down the plane. The magnitude of the acceleration is 4.9 m/s^2.

LEARN The normal force F_N on the block must be equal to $mg\cos\theta$ so that the block is in contact with the surface of the incline at all time. When the cord is cut, the block has an acceleration $a = -g\sin\theta$, which in the limit $\theta \to 90°$ becomes $-g$, as in the case of a free fall.

18. The free-body diagram of the cars is shown on the right. The force exerted by John Massis is

$$F = 2.5mg = 2.5(80\text{ kg})(9.8\text{ m/s}^2) = 1960\text{ N}.$$

Since the motion is along the horizontal x-axis, using Newtonôs second law, we have $Fx = F\cos\theta = Ma_x$, where M is the total mass of the railroad cars. Thus, the acceleration of the cars is



$$a_x = \frac{F\cos\theta}{M} = \frac{(1960\text{ N})\cos 30°}{(7.0\times10^5\text{ N}/9.8\text{ m/s}^2)} = 0.024\text{ m/s}^2.$$

Using Eq. 2-16, the speed of the car at the end of the pull is

$$v_x = \sqrt{2a_x\Delta x} = \sqrt{2(0.024\text{ m/s}^2)(1.0\text{ m})} = 0.22\text{ m/s}.$$

19. **THINK** In this problem we're interested in the force applied to a rocket sled to accelerate it from rest to a given speed in a given time interval.

EXPRESS

In terms of magnitudes, Newton's second law of motion is $F = ma$, where $F = |\vec{F}_{\text{net}}|$, $a = |\vec{a}|$, and m is the (always positive) mass. The magnitude of the acceleration can be found using constant acceleration kinematics. Solving $v = v_0 + at$ for the case where it starts from rest, we have $a = v/t$ (which we interpret in terms of magnitudes, making specification of coordinate directions unnecessary). The velocity is

$$v = (1650 \text{ km/h})\,(1000 \text{ m/km})/(3600 \text{ s/h}) = 458 \text{ m/s},$$

so

$$F = ma = m\frac{v}{t} = (550\,\text{kg})\,\frac{458\,\text{m/s}}{2.0\,\text{s}} = 1.3\times10^{5}\ \text{N}.$$

LEARN From the expression $F = mv/t$, we see that the shorter the time to attain a given speed, the greater the force required.

20. The stopping force $\vec{F}$ and the path of the passenger are horizontal. Our $+x$ axis is in the direction of the passengerôs motion, so that the passengerôs acceleration (óódecelerationò) is negative-valued and the stopping force is in the ï x direction: $\vec{F} = -F\,\hat{i}$. Using Eq. 2-16 with

$$v_0 = (63 \text{ km/h})(1000 \text{ m/km})/(3600 \text{ s/h}) = 17.5 \text{ m/s}$$

and $v = 0$, the acceleration is found to be

$$v^2 = v_0^2 + 2a\Delta x \quad \Rightarrow \quad a = -\frac{v_0^2}{2\Delta x} = -\frac{(17.5 \text{ m/s})^2}{2(0.65 \text{ m})} = -236 \text{ m/s}^2 .$$

Assuming there are no significant horizontal forces other than the stopping force, Eq. 5-1 leads to

$$\vec{F} = m\vec{a} \quad \Rightarrow \quad -F = (41 \text{ kg})\left(-236 \text{ m/s}^2\right)$$

which results in $F = 9.7 \times 10^3$ N.

2121. (a) The slope of each graph gives the corresponding component of acceleration. Thus, we find a_x = 3.00 m/s^2 and a_y = ï 5.00 m/s^2. The magnitude of the acceleration vector is therefore

$$a = \sqrt{(3.00 \text{ m/s}^2)^2 + (-5.00 \text{ m/s}^2)^2} = 5.83 \text{ m/s}^2,$$

and the force is obtained from this by multiplying with the mass (m = 2.00 kg). The result is $F = ma$ =11.7 N.

(b) The direction of the force is the same as that of the acceleration:

θ = tan$^{\text{ï} 1}$ [(ï 5.00 m/s^2)/(3.00 m/s^2)] = ï 59.0°.

22. (a) The coin undergoes free fall. Therefore, with respect to ground, its acceleration is

$$\vec{a}_{\text{coin}} = \vec{g} = (-9.8\ \text{m/s}^2)\hat{j}.$$

(b) Since the customer is being pulled down with an acceleration of

$$\vec{a}'_{\text{customer}} = 1.24\vec{g} = (-12.15\ \text{m/s}^2)\hat{j},$$

the acceleration of the coin with respect to the customer is

$$\vec{a}_{\text{rel}} = \vec{a}_{\text{coin}} - \vec{a}'_{\text{customer}} = (-9.8\ \text{m/s}^2)\hat{j} - (-12.15\ \text{m/s}^2)\hat{j} = (+2.35\ \text{m/s}^2)\hat{j}.$$

(c) The time it takes for the coin to reach the ceiling is

$$t = \sqrt{\frac{2h}{a_{\text{rel}}}} = \sqrt{\frac{2(2.20\ \text{m})}{2.35\ \text{m/s}^2}} = 1.37\ \text{s}.$$

(d) Since gravity is the only force acting on the coin, the actual force on the coin is

$$\vec{F}_{\text{coin}} = m\vec{a}_{\text{coin}} = m\vec{g} = (0.567\times10^{-3}\ \text{kg})(-9.8\ \text{m/s}^2)\hat{j} = (-5.56\times10^{-3}\ \text{N})\hat{j}.$$

(e) In the customer's frame, the coin travels upward at a constant acceleration. Therefore, the apparent force on the coin is

$$\vec{F}_{\text{app}} = m\vec{a}_{\text{rel}} = (0.567\times10^{-3}\ \text{kg})(+2.35\ \text{m/s}^2)\hat{j} = (+1.33\times10^{-3}\ \text{N})\hat{j}.$$

23. We note that the rope is 22.0° from vertical, and therefore 68.0° from horizontal.

(a) With T = 760 N, then its components are

$$\vec{T} = T\cos 68.0°\,\hat{i} + T\sin 68.0°\,\hat{j} = (285\text{N})\,\hat{i} + (705\text{N})\,\hat{j}.$$

(b) No longer in contact with the cliff, the only other force on Tarzan is due to earth's gravity (his weight). Thus,

$$\vec{F}_{\text{net}} = \vec{T} + \vec{W} = (285\text{ N})\hat{i} + (705\text{ N})\,\hat{j} - (860\text{ N})\,\hat{j} = (285\text{ N})\hat{i} - (155\text{ N})\,\hat{j}$$

(c) In a manner that is efficiently implemented on a vector-capable calculator, we convert from rectangular (x, y) components to magnitude-angle notation so that the net force has a magnitude of 324 N.

(c) The angle (see part (c)) has been found to be –28.5°, or 28.5° below horizontal (away from the cliff).

(d) Since $\vec{a} = \vec{F}_{\text{net}}/m$ where $m = W/g$ = 87.8 kg, we obtain $\vec{a} = 3.69\text{ m/s}^2$.

(e) Eq. 5-1 requires that $\vec{a} \parallel \vec{F}_{\text{net}}$ so that the angle is also –28.5°, or 28.5° below horizontal (away from the cliff).

24. We take rightward as the $+x$ direction. Thus, $\vec{F}_1 = (30\text{ N})\hat{i}$. In each case, we use Newton's second law $\vec{F}_1 + \vec{F}_2 = m\vec{a}$ where m = 2.0 kg.

(a) If $\vec{a} = (+10\text{ m/s}^2)\,\hat{i}$, then the equation above gives $\vec{F}_2 = (-10\text{ N})\hat{i}$

(b) If , $\vec{a} = (+20\,\text{m/s}^2)\,\hat{i}$, then that equation gives $\vec{F}_2 = (10\text{ N})\hat{i}$

(c) If $\vec{a} = 0$, then the equation gives $\vec{F}_2 = (-30\text{ N})\hat{i}$

(d) If $\vec{a} = (-10\text{ m/s}^2)\,\hat{i}$, the equation gives $\vec{F}_2 = (-50\text{ N})\hat{i}$

(e) If $\vec{a} = (-20\text{ m/s}^2)\,\hat{i}$, the equation gives $\vec{F}_2 = (-70\text{ N})\hat{i}$

25. (a) The acceleration is $a = \dfrac{F}{m} = \dfrac{20\ \text{N}}{900\,\text{kg}} = 0.022\ \text{m/s}^2$.

(b) The distance traveled in 1 day (= 86400 s) is

$$s = \frac{1}{2}at^2 = \frac{1}{2}\left(0.0222\,\text{m/s}^2\right)\left(86400\,\text{s}\right)^2 = 8.3 \times 10^7\ \text{m} \ .$$

(b) The speed it will be traveling is given by

$$v = at = \left(0.0222\ \text{m/s}^2\right)\left(86400\ \text{s}\right) = 1.9 \times 10^3\ \text{m/s} \ .$$

26. Some assumptions (not so much for realism but rather in the interest of using the given information efficiently) are needed in this calculation: we assume the fishing line and the path of the salmon are horizontal. Thus, the weight of the fish contributes only (via Eq. 5-12) to information about its mass ($m = W/g = 9.2$ kg). Our $+x$ axis is in the direction of the salmonôs velocity (away from the fisherman), so that its acceleration (óódecelerationò) is negative-valued and the force of tension is in the ïx direction: $\vec{T} = -T$. We use Eq. 2-16 and SI units (noting that $v = 0$).

$$v^2 = v_0^2 + 2a\Delta x \;\Rightarrow\; a = -\frac{v_0^2}{2\Delta x} = -\frac{(2.8\text{ m/s})^2}{2(0.11\text{ m})} = -36\text{ m/s}^2.$$

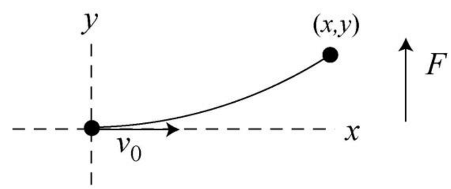
Assuming there are no significant horizontal forces other than the tension, Eq. 5-1 leads to

$$\vec{T} = m\vec{a} \;\Rightarrow\; -T = (9.2\,\text{kg})(-36\,\text{m/s}^2)$$

which results in $T = 3.3 \times 10^2$ N.

27. **THINK** An electron moving horizontally is under the influence of a vertical force. Its path will be deflected toward the direction of the applied force.

EXPRESS The setup is depicted in the following figure. The acceleration of the electron is vertical and for all practical purposes the only force acting on it is the electric force. The force of gravity is negligible. We take the $+x$ axis to be in the direction of the initial velocity v_0 and the $+y$ axis to be in the direction of the electric force, and place the origin at the initial position of the electron.



As the force and acceleration are constant, we use the equation $x = v_0 t$ and

$$y = \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{F}{m}\right)t^2.$$

ANALYZE The time taken by the electron to travel a distance x (= 35 mm) horizontally is $t = x/v_0$ and its deflection in the direction of the force is

$$y = \frac{1}{2}\frac{F}{m}\left(\frac{x}{v_0}\right)^2 = \frac{1}{2}\left(\frac{5.5\times10^{-16}\text{ N}}{9.11\times10^{-31}\text{ kg}}\right)\left(\frac{35\times10^{-3}\text{ m}}{1.5\times10^{7}\text{ m/s}}\right)^2 \approx 1.6\times10^{-3}\text{ m}.$$

LEARN Because the applied force is constant, the acceleration in the y-direction is also constant and the path is parabolic with $y \propto x^2$.

28. The stopping force $\vec{F}$ and the path of the car are horizontal. Thus, the weight of the car contributes only (via Eq. 5-12) to information about its mass ($m = W/g$ = 1327 kg). Our $+x$ axis is in the direction of the carôs velocity, so that its acceleration (óódecelerationò) is negative-valued and the stopping force is in the ïx direction: $\vec{F} = -F\,\hat{\text{i}}$.

(a) We use Eq. 2-16 and SI units, noting that v = 0 and v_0 = (35 km/h)(1000 m/km)/(1 h/3600 s) = 9.72 m/s.

$$v^2 = v_0^2 + 2a\Delta x \quad \Rightarrow \quad a = -\frac{v_0^2}{2\Delta x} = -\frac{(9.72\text{ m/s})^2}{2(15\text{ m})}$$

which yields a = ï 3.15 m/s^2. Assuming there are no significant horizontal forces other than the stopping force, Eq. 5-1 leads to

$$\vec{F} = m\vec{a} \quad \Rightarrow \quad -F = (1327\text{ kg})\,(-3.15\text{ m/s}^2)$$

which results in $F = 4.2 \times 10^3$ N.

(b) Equation 2-11 readily yields t = ï v_0/a = 3.1 s.

(c) Keeping F the same means keeping the acceleration a the same, in which case (since v = 0) Eq. 2-16 expresses a direct proportionality between Δx and v_0^2. Therefore, doubling v_0 means quadrupling Δx. That is, the new over the old stopping distances is a factor of 4.0.

(d) Equation 2-11 illustrates a direct proportionality between t and v_0 so that doubling one means doubling the other. That is, the new time of stopping is a factor of 2.0 greater than the one found in part (b).

29. We choose up as the $+y$ direction, so $\vec{a} = (-2.00\,\text{m/s}^2)\hat{j}$ (which, without the unit-vector, we denote as a since this is a one-dimensional problem. We obtain the firefighter's mass as

$$m = \frac{W}{g} = 70.3\,\text{kg}.$$

(a) We denote the force exerted by the pole on the firefighter $\vec{F}_{\text{fp}} = F_{\text{fp}}\,\hat{j}$ and apply the relation $\vec{F}_{\text{net}} = m\vec{a}$, we have

$$F_{\text{fp}} - F_g = ma \quad \Rightarrow \quad F_{\text{fp}} - 689\text{ N} = (70.3\text{ kg})(-2.00\text{ m/s}^2)$$

which yields F_{fp} = 548 N.

(b) The fact that the result is positive does mean that $\vec{F}_{\text{fp}}$ points toward upward.

(c) Newton's third law of motion indicates that $\vec{F}_{\text{fp}} = -\vec{F}_{\text{pf}}$, which leads to the conclusion that $|\vec{F}_{\text{pf}}| = 548\text{ N}.$

(d) The direction of $\vec{F}_{\text{pf}}$ is toward downward.

30. The stopping force $\vec{F}$ and the path of the toothpick are horizontal. Our $+x$ axis is in the direction of the toothpickôs motion, so that the toothpickôs acceleration (óódecelerationò) is negative-valued and the stopping force is in the ï x direction: $\vec{F} = -F\,\check{\text{F}}$. Using Eq. 2-16 with v_0 = 220 m/s and v = 0, the acceleration is found to be

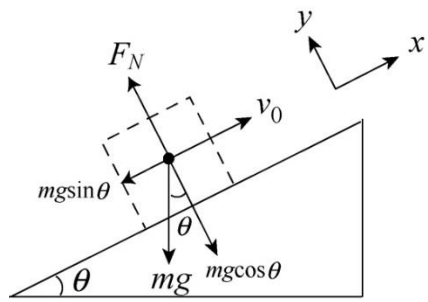
$$v^2 = v_0^2 + 2a\Delta x \quad\Rightarrow\quad a = -\frac{v_0^2}{2\Delta x} = -\frac{(205\text{ m/s})^2}{2\left(0.015\text{ m}\right)} = -1.40\times10^{6}\text{ m/s}^2.$$

Thus, the magnitude of the force exerted by the branch on the toothpick is

$$F = m\,|\,a\,| = (1.3\times10^{-4}\text{ kg})(1.40\times10^{6}\text{ m/s}^2) = 1.8\times10^{2}\text{ N}.$$

31. **THINK** In this problem we analyze the motion of a block sliding up an inclined plane and back down.

EXPRESS The free-body diagram for the given situation is shown below. $\vec{F}_N$ is the normal force of the plane on the block and $m\vec{g}$ is the force of gravity on the block. We take the +*x* direction to be up the incline, and the +*y* direction to be in the direction of the normal force exerted by the incline on the block. The *x* component of Newtonôs second law is then $mg\sin\theta = -ma$; thus, the acceleration is $a = -g\sin\theta$. Placing the origin at the bottom of the plane, the kinematic equations for motion along the *x* axis that we will use are $v^2 = v_0^2 + 2ax$ and $v = v_0 + at$. The block momentarily stops at its highest point, where $v = 0$; according to the second equation, this occurs at time $t = -v_0/a$.



ANALYZE (a) The position at which the block stops is

$$x = -\frac{1}{2}\frac{v_0^2}{a} = -\frac{1}{2}\left(\frac{(2.77\ \text{m/s})^2}{-(9.8\ \text{m/s}^2)\sin 28.0°}\right) = 0.834\ \text{m}.$$

(b) The time it takes for the block to get there is

$$t = \frac{v_0}{a} = -\frac{v_0}{-g\sin\theta} = -\frac{2.77\,\text{m/s}}{-(9.8\,\text{m/s}^2)\sin 28.0°} = 0.602\,\text{s}.$$

(c) That the return-speed is identical to the initial speed is to be expected since there are no dissipative forces in this problem. In order to prove this, one approach is to set $x = 0$ and solve $x = v_0 t + \frac{1}{2}at^2$ for the total time (up and back down) *t*. The result is

$$t = -\frac{2v_0}{a} = -\frac{2v_0}{-g\sin\theta} = -\frac{2(2.77\ \text{m/s})}{-(9.8\ \text{m/s}^2)\sin 28.0°} = 1.204\ \text{s}.$$

The velocity when it returns is therefore

$$v = v_0 + at = v_0 - gt\sin\theta = 2.77\ \text{m/s} - (9.8\,\text{m/s}^2)(1.204\,\text{s})\sin 28.0° = -2.77\ \text{m/s}.$$

The negative sign indicates that the direction is down the plane.

LEARN As expected, the speed of the block when it gets back to the bottom of the incline is the same as its initial speed. As we shall see in Chapter 8, this is a consequence of energy conservation. If friction is present, then the return speed will be smaller than the initial speed.

32. (a) Using notation suitable to a vector-capable calculator, the $\vec{F}_{\text{net}} = 0$ condition becomes

$$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = (6.00 \angle 150^\circ) + (7.00 \angle -60.0^\circ) + \vec{F}_3 = 0 .$$

Thus,

$$\vec{F}_3 = (1.70\ \text{N})\,\hat{\text{i}} + (3.06\ \text{N})\hat{\text{j}}.$$

(b) A constant velocity condition requires zero acceleration, so the answer is the same.

(c) Now, the acceleration is

$$\vec{a} = (13.0\ \text{m/s}^2)\,\hat{\text{i}} - (14.0\ \text{m/s}^2)\,\hat{\text{j}}.$$

Using $\vec{F}_{\text{net}} = m\,\vec{a}$ (with m = 0.025 kg) we now obtain

$$\vec{F}_3 = (2.02\ \text{N})\,\hat{\text{i}} + (2.71\ \text{N})\,\hat{\text{j}}.$$

33. The free-body diagram for the given situation is shown below. Let $\vec{T}$ be the tension of the cable and $m\vec{g}$ be the force of gravity. If the upward direction is positive, then Newtonôs second law is T ï $mg = ma$, where a is the acceleration. Thus, the tension is $T = m(g + a)$. We use constant acceleration kinematics to find the acceleration (where $v = 0$ is the final velocity, v_0 = ï 9.0 m/s is the initial velocity, and $y = -38$ m is the coordinate at the stopping point). Consequently, $v^2 = v_0^2 + 2ay$ leads to

$$a = -\frac{v_0^2}{2y} = -\frac{(-9.0\ \text{m/s})^2}{2(-38\ \text{m})} = 1.06\ \text{m/s}^2.$$

The tension is calculated as follows:

$$\begin{aligned} T &= m(g + a) = (1500\ \text{kg})\ (9.8\ \text{m/s}^2 + 1.06\ \text{m/s}^2) \\ &= 1.6 \times 10^4\ \text{N}. \end{aligned}$$

34. We resolve this horizontal force into appropriate components.

(a) Newtonôs second law applied to the x-axis produces

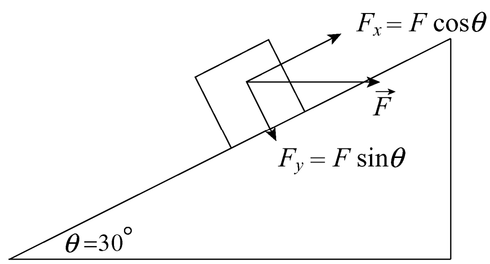
$$F\ \cos\theta - mg\ \sin\theta = ma.$$

For $a = 0$, this yields $F = 651$ N.

(b) Applying Newtonôs second law to the y axis (where there is no acceleration), we have

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

which yields the normal force $F_N = 1.30 \times 10^3$ N.



35. The acceleration vector as a function of time is

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}(7.00t\,\hat{i} + 2.00t^2\,\hat{j})\text{ m/s} = (7.00\,\hat{i} + 4.00t\,\hat{j})\text{ m/s}^2.$$

(a) The magnitude of the force acting on the particle is

$$F = ma = m\,|\,\vec{a}\,| = (2.50)\sqrt{(7.00)^2 + (4.00t)^2} = (2.50)\sqrt{49.0 + 16.0\,t^2}\text{ N.}$$

Thus, $F = 35.0\text{ N}$ corresponds to $t = 3.031\text{ s}$, and the acceleration vector at this instant is

$$\vec{a} = [7.00\,\hat{i} + 4.00(3.031)\,\hat{j}]\text{ m/s}^2 = (7.00\text{ m/s}^2)\,\hat{i} + (12.12\text{ m/s}^2)\,\hat{j}.$$

The angle $\vec{a}$ makes with $+x$ is

$$\theta_a = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{12.12\text{ m/s}^2}{7.00\text{ m/s}^2}\right) = 60.0°.$$

(b) The velocity vector at $t = 1.415\text{ s}$ is

$$\vec{v} = \left[7.00(3.031)\,\hat{i} + 2.00(3.031)^2\,\hat{j}\right]\text{m/s} = (21.22\text{ m/s})\,\hat{i} + (18.38\text{ m/s})\,\hat{j}.$$

Therefore, the angle $\vec{v}$ makes with $+x$ is

$$\theta_v = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{18.38\text{ m/s}}{21.22\text{ m/s}}\right) = 40.9°.$$

36. (a) Constant velocity implies zero acceleration, so the ñuphillò force must equal (in magnitude) the ñdownhillò force: $T = mg \sin\theta$. Thus, with m = 45 kg and $\theta = 8.0°$, the tension in the rope equals 61 N.

(b) With an uphill acceleration of 0.10 m/s^2, Newtonôs second law (applied to the x axis) yields

$$T - mg\sin\theta = ma \quad\Rightarrow\quad T - (45\ \text{kg})(9.8\ \text{m/s}^2)\sin 8.0° = (45\ \text{kg})(0.10\ \text{m/s}^2)$$

which leads to T = 66 N.

37. (a) Since friction is negligible, the force of the boy is the only horizontal force acting on the sled. The vertical forces (the force of gravity and the normal force of the ice) sum to zero. The acceleration of the sled is

$$a_s = \frac{F}{m_s} = \frac{4.2\,\text{N}}{6.5\,\text{kg}} = 0.65\ \text{m/s}^2\ .$$

(b) According to Newtonôs third law of motion, the force of the sled on the boy is also 4.2 N. His acceleration is

$$a_b = \frac{F}{m_b} = \frac{4.2\,\text{N}}{35\,\text{kg}} = 0.12\ \text{m/s}^2\ .$$

(c) The accelerations of the sled and the boy are in opposite directions. Assuming the boy starts at the origin and moves in the +x direction, his coordinate is given by $x_b = \frac{1}{2}a_b t^2$. The sled starts at x_0 = 12 m and moves in the ïx direction. Its coordinate is given by $x_s = x_0 - \frac{1}{2}a_s t^2$. They meet when $x_b = x_s$, or

$$\frac{1}{2}a_b t^2 = x_0 - \frac{1}{2}a_s t^2.$$

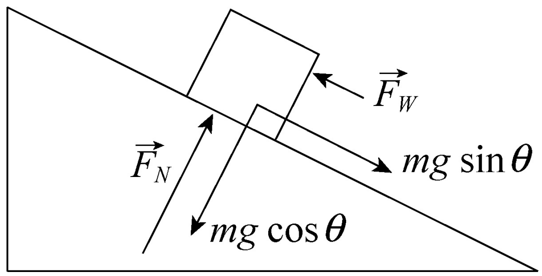
This occurs at the time

$$t = \sqrt{\frac{2x_0}{a_b + a_s}}.$$

By then, the boy has gone the distance

$$x_b = \frac{1}{2}a_b t^2 = \frac{x_0 a_b}{a_b + a_s} = \frac{(12\ \text{m})(0.12\ \text{m/s}^2)}{0.12\ \text{m/s}^2 + 0.65\ \text{m/s}^2} = 1.9\ \text{m}.$$

38. We label the 50 kg skier ñm,ò which is represented as a block in the figure shown. The force of the wind is denoted $\vec{F}_w$ and might be either ñuphillò or ñdownhillò (it is shown uphill in our sketch). The incline angle θ is 10°. The $-x$ direction is downhill.



(a) Constant velocity implies zero acceleration; thus, application of Newtonôs second law along the x axis leads to

$$mg \sin\theta - F_w = 0 .$$

This yields F_w = 85 N (uphill).

(b) Given our coordinate choice, we have $a = |a| = 1.0$ m/s^2. Newtonôs second law

$$mg \sin\theta - F_w = ma$$

now leads to F_w = 35 N (uphill).

(c) Continuing with the forces as shown in our figure, the equation

$$mg \sin\theta - F_w = ma$$

will lead to F_w = ï 15 N when $|a|$ = 2.0 m/s^2. This simply tells us that the wind is opposite to the direction shown in our sketch; in other words, $\vec{F}_w = 12\ \text{N}$ *downhill*.

39. The solutions to parts (a) and (b) have been combined here. The free-body diagram is shown below, with the tension of the string $\vec{T}$, the force of gravity $m\vec{g}$, and the force of the air $\vec{F}$. Our coordinate system is shown. Since the bead is motionless, the net force on it is zero, and the x and the y components of the equations are given by

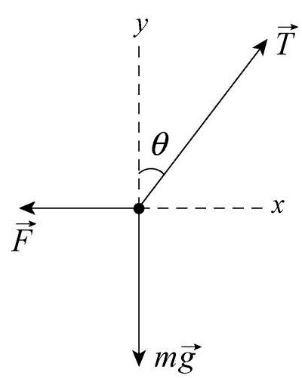
$$T \sin\theta - F = 0 \text{ and } T\cos\theta - mg = 0,$$

where $\theta = 40°$. We answer the questions in the reverse order. Solving $T\cos\theta - mg = 0$ for the tension, we get

$$T = mg/\cos\theta = (2.5 \times 10^{-4}\ \text{kg})\,(9.8\ \text{m/s}^2)\,/\,\cos 40° = 3.198 \times 10^{-3}\ \text{N} \approx 3.2 \times 10^{-3}\ \text{N}.$$

Solving $T\sin\theta - F = 0$ for the force of the air:

$$F = T\sin\theta = (3.198 \times 10^{-3}\ \text{N})\sin 40° = 2.1 \times 10^{-3}\ \text{N}.$$



40. The acceleration of an object (neither pushed nor pulled by any force other than gravity) on a smooth inclined plane of angle θ is a = ï g sinθ. The slope of the graph shown with the problem statement indicates a = ï 2.50 m/s^2. Therefore, we find $\theta = 14.8°$.

Examining the forces perpendicular to the incline (which must sum to zero since there is no component of acceleration in this direction) we find $F_N = mg\cos\theta$, where m = 4.50 kg.

Thus, the normal (perpendicular) force exerted at the box/ramp interface is 42.6 N.

41. The mass of the bundle is m = (450 N)/(9.80 m/s^2) = 45.92 kg and we choose $+y$ upward.

(a) Newtonõs second law, applied to the bundle, leads to

$$T - mg = ma \;\Rightarrow\; a = \frac{390\ \text{N} - 450\ \text{N}}{45.92\ \text{kg}} = -1.307\ \text{m/s}^2 \approx -1.3\ \text{m/s}^2.$$

which yields a = ï 1.3 m/s^2 (or $|a|$ = 1.3 m/s^2) for the acceleration. The minus sign in the result indicates the acceleration vector points down. Any downward acceleration of magnitude greater than this is also acceptable (since that would lead to even smaller values of tension).

(b) We use the equation

$$v^2 = v_0^2 + 2a(x - x_0)\,,$$

where $(x - x_0)$ is Δx (with Δx replaced by Δy = ï 6.1 m). We assume v_0 = 0. The speed is

$$|v| = \sqrt{2a\Delta y} = \sqrt{2\left(-1.307\ \text{m/s}^2\right)\left(-6.2\ \text{m}\right)} = 4.0\ \text{m/s}.$$

For downward accelerations greater than 1.3 m/s^2, the speeds at impact will be larger than 4.0 m/s.

42. The direction of motion (the direction of the barge's acceleration) is $+\hat{i}$, and $+\hat{j}$ is chosen so that the pull $\vec{F}_{\text{h}}$ from the horse is in the first quadrant. The components of the unknown force of the water are denoted simply F_x and F_y.

(a) Newton's second law applied to the barge, in the x and y directions, leads to

$$(8600\ \text{N})\cos(18^{0}) + F_x = ma$$
$$(8600\ \text{N})\sin(18^{0}) + F_y = 0$$

respectively. Plugging in a = 0.12 m/s^2 and m = 9500 kg, we obtain $F_x = -7.04 \times 10^3$ N and $F_y = -2.66 \times 10^3$ N. The magnitude of the force of the water is therefore

$$F_{\text{water}} = \sqrt{F_x^2 + F_y^2} = 7.5 \times 10^3\ \text{N}.$$

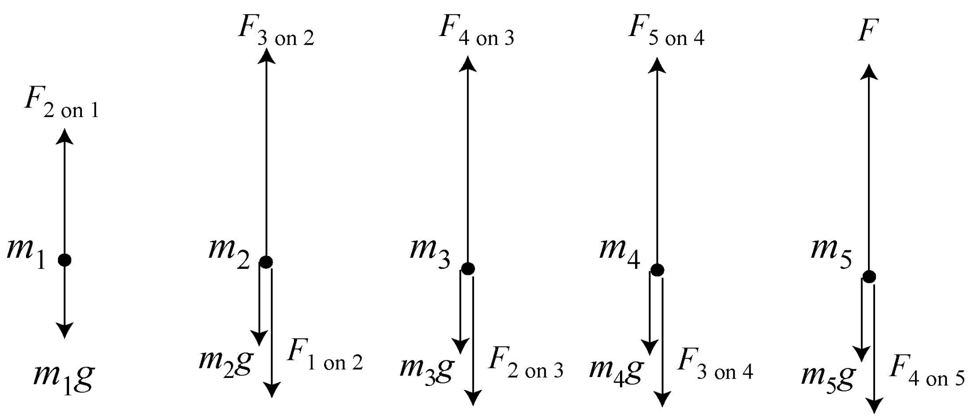
(b) Its angle measured from $+\hat{i}$ is either

$$\phi = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{-2.66\times10^3\ \text{N}}{-7.04\times10^3\ \text{N}}\right) = 20.7°\ \text{or}\ 200.7°.$$

The signs of the components indicate the latter is correct, so $\vec{F}_{\text{water}}$ is at 200.7° measured counterclockwise from the line of motion (+x axis).

43. **THINK** A chain of five links is accelerated vertically upward by an external force. We are interested in the forces exerted by one link on its adjacent one.

EXPRESS The links are numbered from bottom to top. The forces on the first link are the force of gravity $m\vec{g}$, downward, and the force $\vec{F}_{2on1}$ of link 2, upward, as shown in the free-body diagram below (not drawn to scale). Take the positive direction to be upward. Then Newtonôs second law for the first link is $F_{2on1} - m_1 g = m_1 a$. The equations for the other links can be written in a similar manner (see below).



ANALYZE

(a) Given that $a = 2.50\text{ m/s}^2$, from $F_{2on1} - m_1 g = m_1 a$, the force exerted by link 2 on link 1 is

$$F_{2on1} = m_1(a+g) = (0.100\text{ kg})(2.5\text{ m/s}^2 + 9.80\text{ m/s}^2) = 1.23\text{ N}.$$

(b) From the free-body diagram above, we see that the forces on the second link are the force of gravity $m_2\vec{g}$, downward, the force $\vec{F}_{1on2}$ of link 1, downward, and the force $\vec{F}_{3on2}$ of link 3, upward. According to Newtonôs third law $\vec{F}_{1on2}$ has the same magnitude as $\vec{F}_{2on1}$. Newtonôs second law for the second link is

$$F_{3on2} - F_{1on2} - m_2 g = m_2 a$$

so

$$F_{3on2} = m_2(a + g) + F_{1on2} = (0.100\text{ kg})\,(2.50\text{ m/s}^2 + 9.80\text{ m/s}^2) + 1.23\text{ N} = 2.46\text{ N}.$$

(c) Newtonôs second law equation for link 3 is F_{4on3} ï F_{2on3} ï $m_3 g = m_3 a$, so

$$F_{4on3} = m_3(a + g) + F_{2on3} = (0.100\text{ N})\,(2.50\text{ m/s}^2 + 9.80\text{ m/s}^2) + 2.46\text{ N} = 3.69\text{ N},$$

where Newtonôs third law implies $F_{2on3} = F_{3on2}$ (since these are magnitudes of the force vectors).

(d) Newtonôs second law for link 4 is

$$F_{5on4}\text{ ï }F_{3on4}\text{ ï }m_4 g = m_4 a,$$

so

$$F_{5on4} = m_4(a + g) + F_{3on4} = (0.100\text{ kg})\,(2.50\text{ m/s}^2 + 9.80\text{ m/s}^2) + 3.69\text{ N} = 4.92\text{ N},$$

where Newtonôs third law implies $F_{3on4} = F_{4on3}$.

(e) Newtonôs second law for the top link is F ï F_{4on5} ï $m_5 g = m_5 a$, so

$$F = m_5(a + g) + F_{4on5} = (0.100\text{ kg})\,(2.50\text{ m/s}^2 + 9.80\text{ m/s}^2) + 4.92\text{ N} = 6.15\text{ N},$$

where $F_{4on5} = F_{5on4}$ by Newtonôs third law.

(f) Each link has the same mass ($m_1 = m_2 = m_3 = m_4 = m_5 = m$) and the same acceleration, so the same net force acts on each of them:

$$F_{\text{net}} = ma = (0.100\text{ kg})\,(2.50\text{ m/s}^2) = 0.250\text{ N}.$$

LEARN In solving this problem we have used both Newtonôs second and third laws. Each pair of links constitutes a third-law force pair, with $\vec{F}_{\text{i on j}} = -\vec{F}_{\text{j on i}}$.

44. (a) The term ñdecelerationò means the acceleration vector is in the direction opposite to the velocity vector (which the problem tells us is downward). Thus (with $+y$ upward) the acceleration is $a = +2.4\ \text{m/s}^2$. Newtonôs second law leads to

$$T - mg = ma \;\Rightarrow\; m = \frac{T}{g + a} = \frac{93\ \text{N}}{9.8\ \text{m/s}^2 + 2.4\ \text{m/s}^2}$$

which yields $m = 7.6$ kg for the mass.

(b) Repeating the above computation (now to solve for the tension) with $a = +2.4\ \text{m/s}^2$ will, of course, lead us right back to $T = 93$ N. Since the direction of the velocity did not enter our computation, this is to be expected.

45. (a) The mass of the elevator is m = (29000 N/9.8 m/s^2) = 2959 kg and (with +y upward) the acceleration is a = +1.5 m/s^2. Newtonôs second law leads to

$$T - mg = ma \;\Rightarrow\; T = m(g + a)$$

which yields $T = 3.34 \times 10^4$ N for the tension.

(b) The term ñdecelerationò means the acceleration vector is in the direction opposite to the velocity vector (which the problem tells us is upward). Thus (with +y upward) the acceleration is now a = ï 1.5 m/s^2, so that the tension is

$$T = m\,(g + a) = 2.46 \times 10^4 \text{ N.}$$

46. With a_{ce} meaning ñthe acceleration of the coin relative to the elevatorò and a_{eg} meaning ñthe acceleration of the elevator relative to the ground,ò we have

$$a_{ce} + a_{eg} = a_{cg} \quad \Rightarrow \quad \text{ï}\,8.30\ \text{m/s}^2 + a_{eg} = \text{ï}\,9.80\ \text{m/s}^2$$

which leads to $a_{eg} = \text{ï}\,1.50\ \text{m/s}^2$. We have chosen upward as the positive y direction. Then Newtonôs second law (in the ñgroundò reference frame) yields $T\ \text{ï}\ m\,g = m\,a_{eg}$, or

$$T = m\,g + m\,a_{eg} = m(g + a_{eg}) = (2000\ \text{kg})(8.30\ \text{m/s}^2) = 16.6\ \text{kN}.$$

47. Using Eq. 4-26, the launch speed of the projectile is

$$v_0 = \sqrt{\frac{gR}{\sin 2\theta}} = \sqrt{\frac{(9.8\ \text{m/s}^2)(69\ \text{m})}{\sin 2(53°)}} = 26.52\ \text{m/s}\ .$$

The horizontal and vertical components of the speed are

$$v_x = v_0 \cos\theta = (26.52\ \text{m/s})\cos 53° = 15.96\ \text{m/s}$$

$$v_y = v_0 \sin\theta = (26.52\ \text{m/s})\sin 53° = 21.18\ \text{m/s}.$$

Since the acceleration is constant, we can use Eq. 2-16 to analyze the motion. The component of the acceleration in the horizontal direction is

$$a_x = \frac{v_x^2}{2x} = \frac{(15.96\ \text{m/s})^2}{2(5.2\ \text{m})\cos 53°} = 40.7\ \text{m/s}^2,$$

and the force component is

$$F_x = ma_x = (85\ \text{kg})(40.7\ \text{m/s}^2) = 3460\ \text{N}.$$

Similarly, in the vertical direction, we have

$$a_y = \frac{v_y^2}{2y} = \frac{(21.18\ \text{m/s})^2}{2(5.2\ \text{m})\sin 53°} = 54.0\ \text{m/s}^2.$$

and the force component is

$$F_y = ma_y + mg = (85\ \text{kg})(54.0\ \text{m/s}^2 + 9.80\ \text{m/s}^2) = 5424\ \text{N}.$$

Thus, the magnitude of the force is

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(3460\ \text{N})^2 + (5424\ \text{N})^2} = 6434\ \text{N} \approx 6.4\times 10^3\ \text{N},$$

to two significant figures.

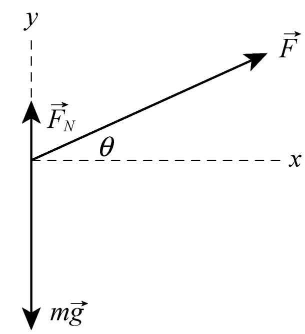
48. Applying Newtonôs second law to cab B (of mass m) we have

$$a = \frac{T}{m} - g = 6.12 \text{ m/s}^2.$$

Next, we apply it to the box (of mass m_b) to find the normal force:

$$F_N = m_b(g + a) = 191 \text{ N}.$$

49. The free-body diagram (not to scale) for the block is shown to the right. $\vec{F}_N$ is the normal force exerted by the floor and $m\vec{g}$ is the force of gravity.



(a) The x component of Newton's second law is $F\cos\theta = ma$, where m is the mass of the block and a is the x component of its acceleration. We obtain

$$a = \frac{F\cos\theta}{m} = \frac{(12.0\,\text{N})\cos 25.0°}{5.00\,\text{kg}} = 2.18\ \text{m/s}^2.$$

This is its acceleration provided it remains in contact with the floor. Assuming it does, we find the value of F_N (and if F_N is positive, then the assumption is true but if F_N is negative then the block leaves the floor). The y component of Newton's second law becomes

$$F_N + F\sin\theta - mg = 0,$$

so

$$F_N = mg - F\sin\theta = (5.00\text{ kg})(9.80\text{ m/s}^2) - (12.0\text{ N})\sin 25.0° = 43.9\text{ N}.$$

Hence the block remains on the floor and its acceleration is $a = 2.18\text{ m/s}^2$.

(b) If F is the minimum force for which the block leaves the floor, then $F_N = 0$ and the y component of the acceleration vanishes. The y component of the second law becomes

$$F\sin\theta - mg = 0 \quad\Rightarrow\quad F = \frac{mg}{\sin\theta} = \frac{(5.00\text{ kg})(9.80\text{ m/s}^2)}{\sin 25.0°} = 116\ \text{N}.$$

(c) The acceleration is still in the x direction and is still given by the equation developed in part (a):

$$a = \frac{F\cos\theta}{m} = \frac{(116\text{ N})\cos 25.0°}{5.00\text{ kg}} = 21.0\,\text{m/s}^2.$$

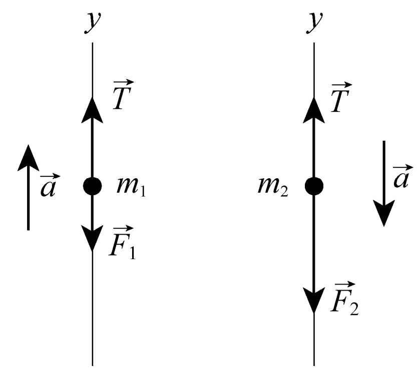
50. (a) The net force on the *system* (of total mass M = 70.0 kg) is the force of gravity acting on the total overhanging mass (m_{BC} = 40.0 kg). The magnitude of the acceleration is therefore $a = (m_{BC}\, g)/M = 5.60\ \text{m/s}^2$. Next we apply Newton's second law to block C itself (choosing *down* as the $+y$ direction) and obtain

$$m_C g - T_{BC} = m_C a.$$

This leads to T_{BC} = 42.0 N.

(b) We use Eq. 2-15 (choosing *rightward* as the $+x$ direction): $\Delta x = 0 + \frac{1}{2}at^2 = 0.175$ m.

51. The free-body diagrams for m_1 and m_2 are shown in the figures below. The only forces on the blocks are the upward tension $\vec{T}$ and the downward gravitational forces $\vec{F}_1 = m_1 g$ and $\vec{F}_2 = m_2 g$. Applying Newtonôs second law, we obtain:



$$T - m_1 g = m_1 a$$

$$m_2 g - T = m_2 a$$

which can be solved to yield

$$a = \left(\frac{m_2 - m_1}{m_2 + m_1}\right) g$$

Substituting the result back, we have

$$T = \left(\frac{2 m_1 m_2}{m_1 + m_2}\right) g$$

(a) With $m_1 = 1.3$ kg and $m_2 = 2.8$ kg, the acceleration becomes

$$a = \left(\frac{2.80\text{ kg} - 1.30\text{ kg}}{2.80\text{ kg} + 1.30\text{ kg}}\right)(9.80\text{ m/s}^2) = 3.59\text{ m/s}^2 \approx 3.6\text{ m/s}^2.$$

(b\)Similarly, the tension in the cord is

$$T = \frac{2(1.30\text{ kg})(2.80\text{ kg})}{1.30\text{ kg} + 2.80\text{ kg}}(9.80\text{ m/s}^2) = 17.4\text{ N} \approx 17\text{ N}.$$

52. Viewing the man-rope-sandbag as a system means that we should be careful to choose a consistent positive direction of motion (though there are other ways to proceed, say, starting with individual application of Newtonós law to each mass). We take *down* as positive for the manós motion and *up* as positive for the sandbagós motion and, without ambiguity, denote their acceleration as a. The net force on the system is the different between the weight of the man and that of the sandbag. The system mass is m_{sys} = 93 kg + 65 kg = 158 kg. Thus, Eq. 5-1 leads to

$$(93\,\text{kg})\,(9.8\,\text{m/s}^2) - (65\,\text{kg})\,(9.8\,\text{m/s}^2) = m_{\text{sys}}\,a$$

which yields a = 1.74 m/s^2. Since the system starts from rest, Eq. 2-16 determines the speed (after traveling Δy = 10.0 m) as follows:

$$v = \sqrt{2a\Delta y} = \sqrt{2(1.74\text{ m/s}^2)(10.0\text{ m})} = 5.9\text{ m/s}.$$

53. (a) To calculate the tension at center of wire A, we note that the mass to be lifted is 1.9 kg and the mass of wire is

$$\frac{1}{2}(0.20\text{ kg}) = 0.10\text{ kg}$$

Thus, the total mass = 1.9 kg + 0.10 kg = 2.0 kg, and

$$T_2 = m(g+a) = (2.0\text{ kg})(9.8\text{ m/s}^2 + 0.50\text{ m/s}^2) = (2.0\text{ kg})(10.3\text{ m/s}^2) = 20.6\text{ N},$$

or about 21 N.

(b) Similarly, for the tension in wire B, we find the total mass to be $2.9\text{ kg} + 1.9\text{ kg} + 0.20\text{ kg} = 5.0\text{ kg}$. Thus,

$$T_1 = m(g+a) = (5.0\text{ kg})(9.8\text{ m/s}^2 + 0.50\text{ m/s}^2) = (5.0\text{ kg})(10.3\text{ m/s}^2) = 51.5\text{ N}$$

or about 52 N.

54. First, we consider all the penguins (1 through 4, counting left to right) as one system, to which we apply Newtonôs second law:

$$T_4 = (m_1 + m_2 + m_3 + m_4)a \quad \Rightarrow \quad 222\,\text{N} = (12\,\text{kg} + m_2 + 15\,\text{kg} + 20\,\text{kg})a.$$

Second, we consider penguins 3 and 4 as one system, for which we have

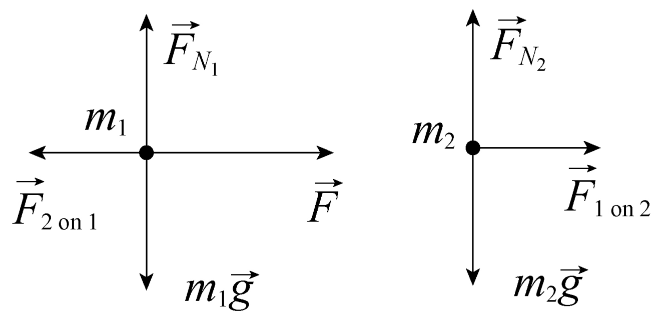
$$T_4 - T_2 = (m_3 + m_4)a$$

$$111\,\text{N} = (15\text{ kg} + 20\,\text{kg})a \quad \Rightarrow \quad a = 3.2\text{ m/s}^2.$$

Substituting the value, we obtain m_2 = 23 kg.

55. **THINK** In this problem a horizontal force is applied to block 1 which then pushes against block 2. Both blocks move together as a rigid connected system.

EXPRESS The free-body diagrams for the two blocks in (a) are shown below. $\vec{F}$ is the applied force and $\vec{F}_{1\text{on}2}$ is the force exerted by block 1 on block 2. We note that $\vec{F}$ is applied directly to block 1 and that block 2 exerts a force $\vec{F}_{2\text{on}1} = -\vec{F}_{1\text{on}2}$ on block 1 (taking Newtonôs third law into account).



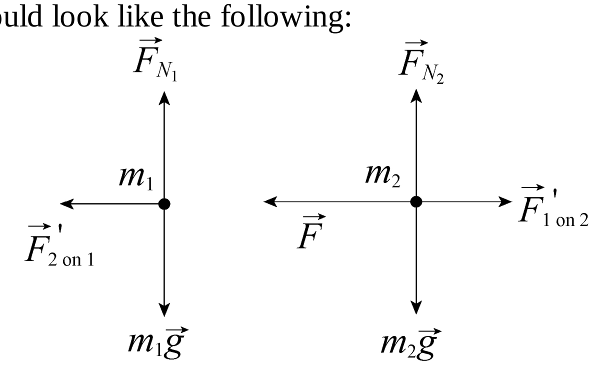
Newtonôs second law for block 1 is $F - F_{2\text{on}1} = m_1 a$, where a is the acceleration. The second law for block 2 is $F_{1\text{on}2} = m_2 a$. Since the blocks move together they have the same acceleration and the same symbol is used in both equations.

ANALYZE

(a) From the second equation we obtain the expression $a = F_{1\text{on}2}/m_2$, which we substitute into the first equation to get $F - F_{2\text{on}1} = m_1 F_{1\text{on}2}/m_2$. Since $F_{2\text{on}1} = F_{1\text{on}2}$ (same magnitude for third-law force pair), we obtain

$$F_{2\text{on}1} = F_{1\text{on}2} = \frac{m_2}{m_1 + m_2}F = \frac{1.2\text{ kg}}{2.3\text{ kg} + 1.2\text{ kg}}(3.2\text{ N}) = 1.1\text{ N}.$$

(b) If $\vec{F}$ is applied to block 2 instead of block 1 (and in the opposite direction), the free-body diagrams would look like the following:



The corresponding force of contact between the blocks would be

$$F'_{2\text{on}1} = F'_{1\text{on}2} = \frac{m_1}{m_1 + m_2} F = \frac{2.3 \text{ kg}}{2.3 \text{ kg} + 1.2 \text{ kg}} (3.2 \text{ N}) = 2.1 \text{ N}.$$

(c) We note that the acceleration of the blocks is the same in the two cases. In part (a), the force $F_{1\text{on}2}$ is the only horizontal force on the block of mass m_2 and in part (b) $F'_{2\text{on}1}$ is the only horizontal force on the block with $m_1 > m_2$. Since $F_{1\text{on}2} = m_2 a$ in part (a) and $F'_{2\text{on}1} = m_1 a$ in part (b), then for the accelerations to be the same, $F'_{2\text{on}1} > F_{1\text{on}2}$, i.e., force between blocks must be larger in part (b).

LEARN This problem demonstrates that when two blocks are being accelerated together under an external force, the contact force between the two blocks is greater if the smaller mass is pushing against the bigger one, as in part (b). In the special case where the two masses are equal, $m_1 = m_2 = m$, $F'_{2\text{on}1} = F_{2\text{on}1} = F/2$.

56. Both situations involve the same applied force and the same total mass, so the accelerations must be the same in both figures.

(a) The (direct) force causing *B* to have this acceleration in the first figure is 15.0 N and we can write

$$15.0 \text{ N} = (12.0 \text{ kg} - m_A)a$$

The (direct) force causing *A* to have this acceleration in the first figure is 10.0 N and we can write

$$10.0 \text{ N} = m_A a$$

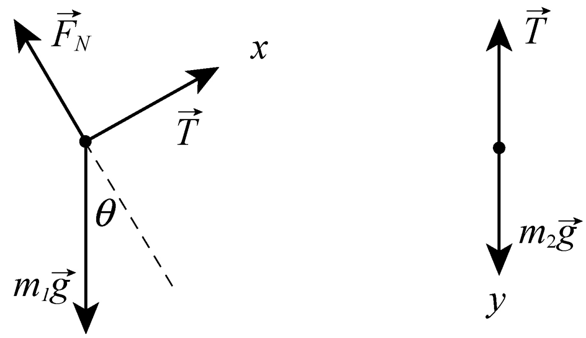
Solving these two equations we get m_A = 4.80 kg and a = 2.08 m/s^2.

(b) For the first figure, the forces acting on *B* can be written as

$$F_a - 15.0 \text{ N} = m_A a$$

which can be solved to give F_a = 25.0 N.

57. The free-body diagrams for the two masses are shown below.



In the diagrams, T is the tension in the cord and $\theta = 30°$ is the angle of the incline. For block 1, we take the $+x$ direction to be up the incline and the $+y$ direction to be in the direction of the normal force $\vec{F}_N$ that the plane exerts on the block. For block 2, we take the $+y$ direction to be down. In this way, the accelerations of the two blocks can be represented by the same symbol a, without ambiguity. Applying Newtonôs second law to the x and y axes for block 1 and to the y axis of block 2, we obtain

$$\begin{aligned} T - m_1 g \sin\theta &= m_1 a \\ F_N - m_1 g \cos\theta &= 0 \\ m_2 g - T &= m_2 a \end{aligned}$$

respectively. The first and third of these equations provide a simultaneous set for obtaining values of a and T. The second equation is not needed in this problem, since the normal force is neither asked for nor is it needed as part of some further computation (such as can occur in formulas for friction).

We add the first and third equations above:

$$m_2 g \text{ ï } m_1 g \sin\theta = m_1 a + m_2 a.$$

Consequently, we find

$$a = \frac{(m_2 - m_1 \sin\theta)g}{m_1 + m_2} = \frac{[4.0\text{ kg} - (8.0\text{ kg})\sin 30.0°]\left(9.80\text{ m/s}^2\right)}{8.0\text{ kg} + 4.0\text{ kg}} = 0\,.$$

The acceleration of the system is zero.

58. The motion of the man-and-chair is positive if upward.

(a) When the man is grasping the rope, pulling with a force equal to the tension T in the rope, the total upward force on the man-and-chair due its two contact points with the rope is $2T$. Thus, Newtonôs second law leads to

$$2T - mg = ma$$

so that when $a = 0$, the tension is $T = \frac{1}{2}mg = \frac{1}{2}(103\text{ kg})(9.8\text{ m/s}^2) = 504.7\text{ N} \approx 505\text{ N}$.

(b) When $a = +1.30\text{ m/s}^2$ the equation in part (a) predicts that the tension will be $T = 572\text{ N}$.

(c) When the man is not holding the rope (instead, the co-worker attached to the ground is pulling on the rope with a force equal to the tension T in it), there is only one contact point between the rope and the man-and-chair, and Newtonôs second law now leads to

$$T - mg = ma$$

so that when $a = 0$, the tension is $T = mg = (103\text{ kg})(9.8\text{ m/s}^2) = 1009\text{ N} \approx 1.01\text{ kN}$.

(d) When $a = +1.30\text{ m/s}^2$, the equation in (c) yields $T = 1.14 \times 10^3$ N, or 1.14 kN.

(e) The rope comes into contact (pulling down in each case) at the left edge and the right edge of the pulley, producing a total downward force of magnitude $2T$ on the ceiling. Thus, in part (a) this gives $2T = 1.01$ kN.

(f) In part (b) the downward force on the ceiling has magnitude $2T = 1.14$ kN.

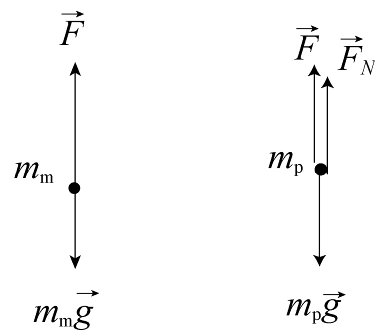
(g) In part (c) the downward force on the ceiling has magnitude $2T = 2.02$ kN.

(h) In part (d) the downward force on the ceiling has magnitude $2T = 2.29$ kN.

59. **THINK** This problem involves the application of Newtonôs third law. As the monkey climbs up a tree, it pulls downward on the rope, but the rope pulls upward on the monkey.

EXPRESS We take $+y$ to be up for both the monkey and the package. The force the monkey pulls downward on the rope has magnitude F.

The free-body diagrams for the monkey and the package are shown to the right (not to scale). According to Newtonôs third law, the rope pulls upward on the monkey with a force of the same magnitude, so Newtonôs second law for forces acting on the monkey leads to



$$F - m_m g = m_m a_m,$$

where m_m is the mass of the monkey and a_m is its acceleration.

Since the rope is massless, $F = T$ is the tension in the rope. The rope pulls upward on the package with a force of magnitude F, so Newtonôs second law for the package is

$$F + F_N - m_p g = m_p a_p,$$

where m_p is the mass of the package, a_p is its acceleration, and F_N is the normal force exerted by the ground on it. Now, if F is the minimum force required to lift the package, then $F_N = 0$ and $a_p = 0$. According to the second law equation for the package, this means $F = m_p g$.

ANALYZE

(a) Substituting $m_p g$ for F in the equation for the monkey, we solve for a_m:

$$a_m = \frac{F - m_m g}{m_m} = \frac{(m_p - m_m)g}{m_m} = \frac{(15\text{ kg} - 10\text{ kg})(9.8\text{ m/s}^2)}{10\text{ kg}} = 4.9\text{ m/s}^2 .$$

(b) As discussed, Newtonôs second law leads to $F - m_p g = m_p a'_p$ for the package and $F - m_m g = m_m a'_m$ for the monkey. If the acceleration of the package is downward, then the acceleration of the monkey is upward, so $a'_m = -a'_p$. Solving the first equation for F

$$F = m_p\left(g + a'_p\right) = m_p\left(g - a'_m\right)$$

and substituting this result into the second equation:

$$m_p(g - a'_m) - m_m g = m_m a'_m ,$$

we solve for a'_m:

$$a'_m = \frac{(m_p - m_m)g}{m_p + m_m} = \frac{(15\text{ kg} - 10\text{ kg})(9.8\text{ m/s}^2)}{15\text{ kg} + 10\text{ kg}} = 2.0\text{ m/s}^2.$$

(c) The result is positive, indicating that the acceleration of the monkey is upward.

(d) Solving the second law equation for the package, the tension in the rope is

$$F = m_p(g - a'_m) = (15\text{ kg})(9.8\text{ m/s}^2 - 2.0\text{ m/s}^2) = 120\text{ N}.$$

LEARN The situations described in (b)-(d) are similar to that of an Atwood machine. With $m_p > m_m$, the package accelerates downward while the monkey accelerates upward.

60. The horizontal component of the acceleration is determined by the net horizontal force.

(a) If the rate of change of the angle is

$$\frac{d\theta}{dt} = (2.00\times10^{-2})°/\text{s} = (2.00\times10^{-2})°/\text{s}\cdot\left(\frac{\pi\ \text{rad}}{180°}\right) = 3.49\times10^{-4}\,\text{rad/s}\,,$$

then, using $F_x = F\cos\theta$, we find the rate of change of acceleration to be

$$\frac{da_x}{dt} = \frac{d}{dt}\left(\frac{F\cos\theta}{m}\right) = -\frac{F\sin\theta}{m}\frac{d\theta}{dt} = -\frac{(15.0\ \text{N})\sin 25.0°}{5.00\ \text{kg}}\left(3.49\times10^{-4}\,\text{rad/s}\right)$$
$$= -4.43\times10^{-4}\ \text{m/s}^3.$$

(b) If the rate of change of the angle is

$$\frac{d\theta}{dt} = -(2.00\times10^{-2})°/\text{s} = -(2.00\times10^{-2})°/\text{s}\cdot\left(\frac{\pi\ \text{rad}}{180°}\right) = -3.49\times10^{-4}\,\text{rad/s}\,,$$

then the rate of change of acceleration would be

$$\frac{da_x}{dt} = \frac{d}{dt}\left(\frac{F\cos\theta}{m}\right) = -\frac{F\sin\theta}{m}\frac{d\theta}{dt} = -\frac{(15.0\ \text{N})\sin 25.0°}{5.00\ \text{kg}}\left(-3.49\times10^{-4}\,\text{rad/s}\right)$$
$$= +4.43\times10^{-4}\ \text{m/s}^3.$$

61. **THINK** As more mass is thrown out of the hot-air balloon, its upward acceleration increases.

EXPRESS The forces on the balloon are the force of gravity $m\vec{g}$ (down) and the force of the air $\vec{F}_a$ (up). We take the $+y$ to be up, and use a to mean the *magnitude* of the acceleration. When the mass is M (before the ballast is thrown out) the acceleration is downward and Newtonôs second law is

$$Mg - F_a = Ma$$

After the ballast is thrown out, the mass is M ï m (where m is the mass of the ballast) and the acceleration is now upward. Newtonôs second law leads to

F_a ï $(M$ ï $m)g = (M$ ï $m)a$.

Combing the two equations allows us to solve for m.

ANALYZE The first equation gives $F_a = M(g$ ï $a)$, and this plugs into the new equation to give

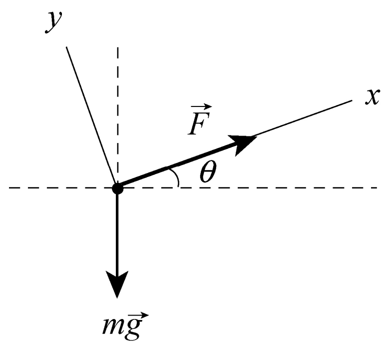
$$M(g - a) - (M - m)g = (M - m)a \;\Rightarrow\; m = \frac{2Ma}{g + a}.$$

LEARN More generally, if a ballast mass m' is tossed, the resulting acceleration is a' which is related to m' via:

$$m' = M\frac{a' + a}{g + a},$$

showing that the more mass thrown out, the greater is the upward acceleration. For $a' = a$, we get $m' = 2Ma/(g + a)$, which agrees with what was found above.

62. To solve the problem, we note that the acceleration along the slanted path depends on only the force components along the path, not the components perpendicular to the path.



(a) From the free-body diagram shown, we see that the net force on the putting shot along the +x-axis is

$$F_{\text{net},x} = F - mg\sin\theta = 380.0\text{ N} - (7.260\text{ kg})(9.80\text{ m/s}^2)\sin 30° = 344.4\text{ N},$$

which in turn gives

$$a_x = F_{\text{net},x}/m = (344.4\text{ N})/(7.260\text{ kg}) = 47.44\text{ m/s}^2.$$

Using Eq. 2-16 for constant-acceleration motion, the speed of the shot at the end of the acceleration phase is

$$v = \sqrt{v_0^2 + 2a_x\Delta x} = \sqrt{(2.500\text{ m/s})^2 + 2(47.44\text{ m/s}^2)(1.650\text{ m})} = 12.76\text{ m/s}.$$

(b) If $\theta = 42°$, then

$$a_x = \frac{F_{\text{net},x}}{m} = \frac{F - mg\sin\theta}{m} = \frac{380.0\text{ N} - (7.260\text{ kg})(9.80\text{ m/s}^2)\sin 42.00°}{7.260\text{ kg}} = 45.78\text{ m/s}^2,$$

and the final (launch) speed is

$$v = \sqrt{v_0^2 + 2a_x\Delta x} = \sqrt{(2.500\text{ m/s})^2 + 2(45.78\text{ m/s}^2)(1.650\text{ m})} = 12.54\text{ m/s}.$$

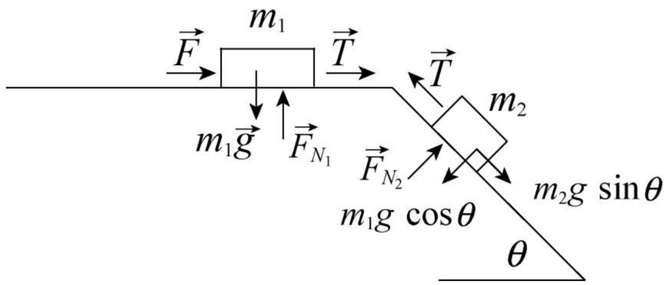
(c) The decrease in launch speed when changing the angle from $30.00°$ to $42.00°$ is

$$\frac{12.76\text{ m/s} - 12.54\text{ m/s}}{12.76\text{ m/s}} = 0.0169 = 1.69\%.$$

63. (a) The acceleration (which equals *F/m* in this problem) is the derivative of the velocity. Thus, the velocity is the integral of *F/m*, so we find the ñareaò in the graph (15 units) and divide by the mass (3) to obtain v ï v_o = 15/3 = 5. Since v_o = 3.0 m/s, then $v = 8.0\,\text{m/s}$.

(b) Our positive answer in part (a) implies $\vec{v}$ points in the +x direction.

64. The $+x$ direction for $m_2 = 1.0$ kg is ñdownhillò and the $+x$ direction for $m_1 = 2.5$ kg is rightward; thus, they accelerate with the same sign.



(a) We apply Newtonôs second law to the x axis of each box:

$$m_2g\ \sin\theta - T = m_2a$$
$$F + T = m_1a$$

Adding the two equations allows us to solve for the acceleration:

$$a = \frac{m_2 g \sin\theta + F}{m_1 + m_2} = \frac{(1.0\text{ kg})(9.8\text{ m/s}^2)\sin 30° + 2.3\text{ N}}{2.5\text{ kg} + 1.0\text{ kg}} = 2.06\text{ m/s}^2$$

where we have used $F = 2.3$ N and $\theta = 30°$. We plug back in and find $T = 2.8$ N.

(b) We consider the ñcriticalò case where the F has reached the *max* value, causing the tension to vanish. The first of the equations in part (a) shows that $a = g\sin 30°$ in this case; thus, $a = 4.9$ m/s^2. This implies (along with $T = 0$ in the second equation in part (a)) that

$$F = (2.5\text{ kg})(4.9\text{ m/s}^2) = 12.3\text{ N} \approx 12\text{ N}$$

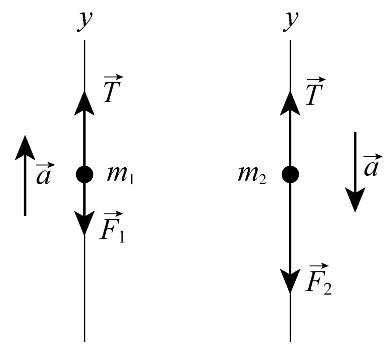
in the critical case.

65. The free-body diagrams for m_1 and m_2 are shown in the figures below. The only forces on the blocks are the upward tension $\vec{T}$ and the downward gravitational forces $\vec{F}_1 = m_1 g$ and $\vec{F}_2 = m_2 g$. Applying Newtonôs second law, we obtain:

$$T - m_1 g = m_1 a$$
$$m_2 g - T = m_2 a$$

which can be solved to give

$$a = \left(\frac{m_2 - m_1}{m_2 + m_1}\right) g$$



(a) At $t = 0$, $m_{10} = 1.30$ kg. With $dm_1/dt = -0.200$ kg/s, we find the rate of change of acceleration to be

$$\frac{da}{dt} = \frac{da}{dm_1}\frac{dm_1}{dt} = -\frac{2m_2 g}{(m_2 + m_{10})^2}\frac{dm_1}{dt} = -\frac{2(2.80\text{ kg})(9.80\text{ m/s}^2)}{(2.80\text{ kg} + 1.30\text{ kg})^2}\left(-0.200\text{ kg/s}\right) = 0.653\text{ m/s}^3.$$

(b) At $t = 3.00$ s, $m_1 = m_{10} + (dm_1/dt)t = 1.30\text{ kg} + (-0.200\text{ kg/s})(3.00\text{ s}) = 0.700\text{ kg}$, and the rate of change of acceleration is

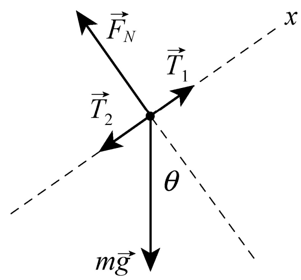
$$\frac{da}{dt} = \frac{da}{dm_1}\frac{dm_1}{dt} = -\frac{2m_2 g}{(m_2 + m_1)^2}\frac{dm_1}{dt} = -\frac{2(2.80\text{ kg})(9.80\text{ m/s}^2)}{(2.80\text{ kg} + 0.700\text{ kg})^2}\left(-0.200\text{ kg/s}\right) = 0.896\text{ m/s}^3.$$

(c) The acceleration reaches its maximum value when

$$0 = m_1 = m_{10} + (dm_1/dt)t = 1.30\text{ kg} + (-0.200\text{ kg/s})t,$$

or $t = 6.50$ s.

66. The free-body diagram is shown below.



Newtonôs second law for the mass m for the x direction leads to

$$T_1 - T_2 - mg\sin\theta = ma,$$

which gives the difference in the tension in the pull cable:

$$T_1 - T_2 = m\left(g\sin\theta + a\right) = \left(2750\text{ kg}\right)\left[(9.8\text{ m/s}^2)\sin 35° + 0.81\text{ m/s}^2\right] = 1.8\times 10^4\text{ N}.$$

67. First we analyze the entire *system* with ñclockwiseò motion considered positive (that is, downward is positive for block C, rightward is positive for block B, and upward is positive for block A): $m_C g$ ï $m_A g = Ma$ (where M = mass of the *system* = 24.0 kg). This yields an acceleration of

$$a = g(m_C - m_A)/M = 1.63 \text{ m/s}^2.$$

Next we analyze the forces just on block C: $m_C g$ ï $T = m_C a$. Thus the tension is

$$T = m_C g(2m_A + m_B)/M = 81.7 \text{ N}.$$

68. We first use Eq. 4-26 to solve for the launch speed of the shot:

$$y - y_0 = (\tan\theta)x - \frac{gx^2}{2(v'\cos\theta)^2}.$$

With $\theta = 34.10°$, $y_0 = 2.11$ m, and $(x, y) = (15.98\text{ m}, 0)$, we find the launch speed to be $v' = 11.88$ m/s. During this phase, the acceleration is

$$a = \frac{v'^2 - v_0^2}{2L} = \frac{(11.85\text{ m/s})^2 - (2.50\text{ m/s})^2}{2(1.65\text{ m})} = 40.87\text{ m/s}^2.$$

Since the acceleration along the slanted path depends on only the force components along the path, not the components perpendicular to the path, the average force on the shot during the acceleration phase is

$$F = m(a + g\sin\theta) = (7.260\text{ kg})\left[40.87\text{ m/s}^2 + (9.80\text{ m/s}^2)\sin 34.10°\right] = 336.6\text{ N}.$$