Chapter 5

1. We apply Newton's second law (specifically, Eq. 5-2).

   (a) We find the x component of the force is

   $$F_x = ma_x = ma\cos 20° = (1.00\,\text{kg})(2.00\,\text{m/s}^2)\cos 20° = 1.88\ \text{N}\ .$$

   (b) The y component of the force is

   $$F_y = ma_y = ma\sin 20° = (1.0\,\text{kg})(2.00\,\text{m/s}^2)\sin 20° = 0.684\ \text{N}\ .$$

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

   $$\vec{F} = F_x\,\hat{\imath} + F_y\,\hat{\jmath} = 1.88\,\hat{\imath} + 0.684\,\hat{\jmath}\ .$$

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

   $$\vec{F}_1 + \vec{F}_2 = \left((3.0\,\text{N})\hat{\imath} + (4.0\,\text{N})\hat{\jmath}\right) + \left((-3.0\,\text{N})\hat{\imath} + (-4.0\,\text{N})\hat{\jmath}\right) = 0$$

   so $\vec{a} = 0$.

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

   $$\frac{\vec{F}_1 + \vec{F}_2}{m} = \frac{\left((3.0\,\text{N})\,\hat{\imath} + (4.0\,\text{N})\hat{\jmath}\right) + \left((-3.0\,\text{N})\,\hat{\imath} + (4.0\,\text{N})\hat{\jmath}\right)}{2.0\,\text{kg}} = 4.0\,\hat{\jmath}\ \text{m/s}^2\ .$$

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

   $$\frac{\vec{F}_1 + \vec{F}_2}{m} = \frac{\left((3.0\,\text{N})\,\hat{\imath} + (4.0\,\text{N})\hat{\jmath}\right) + \left((3.0\,\text{N})\hat{\imath} + (-4.0\,\text{N})\hat{\jmath}\right)}{2.0\,\text{kg}} = 3.0\,\hat{\imath}\ \text{m/s}^2\ .$$

3. We are only concerned with horizontal forces in this problem (gravity plays no direct role). We take East as the $+x$ direction and North as $+y$. This calculation is efficiently implemented on a vector capable calculator, using magnitude-angle notation (with SI units understood).

   $$\vec{a} = \frac{\vec{F}}{m} = \frac{(9.0\ \angle\ 0°) + (8.0\ \angle\ 118°)}{3.0} = (2.9\ \angle\ 53°)$$

   Therefore, the acceleration has a magnitude of 2.9 m/s^2.

4. Since $\vec{v} = \text{constant}$, we have $\vec{a} = 0$, which implies
$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 = m\vec{a} = 0 \ .$$
Thus, the other force must be
$$\vec{F}_2 = -\vec{F}_1 = -2\hat{\imath} + 6\hat{\jmath} \text{ N} \ .$$

5. Since the velocity of the particle does not change, it undergoes no acceleration and must therefore be subject to zero net force. Therefore,
$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0 \ .$$
Thus, the third force $\vec{F}_3$ is given by
$$\begin{aligned} \vec{F}_3 &= -\vec{F}_1 - \vec{F}_2 \\ &= -\left(2\,\hat{\imath} + 3\,\hat{\jmath} - 2\,\hat{k}\right) - \left(-5\,\hat{\imath} + 8\,\hat{\jmath} - 2\,\hat{k}\right) \\ &= 3\,\hat{\imath} - 11\,\hat{\jmath} + 4\,\hat{k} \end{aligned}$$
in Newtons. The specific value of the velocity is not used in the computation.

6. 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 $\vec{a} = \left(\vec{F}_1 + \vec{F}_2 + \vec{F}_3\right)/m$.

   (a) The forces exerted by the three astronauts can be expressed in unit-vector notation as follows:
$$\begin{aligned} \vec{F}_1 &= 32(\cos 30^\circ\,\hat{\imath} + \sin 30^\circ\,\hat{\jmath}) \\ &= 27.7\,\hat{\imath} + 16\,\hat{\jmath} \\ \vec{F}_2 &= 55(\cos 0^\circ\,\hat{\imath} + \sin 0^\circ\,\hat{\jmath}) \\ &= 55\,\hat{\imath} \end{aligned}$$
in Newtons, and
$$\vec{F}_3 = 41\left(\cos(-60^\circ)\hat{\imath} + \sin(-60^\circ)\hat{\jmath}\right) = 20.5\,\hat{\imath} - 35.5\,\hat{\jmath}$$
in Newtons. The resultant acceleration of the asteroid of mass $m = 120$ kg is therefore
$$\begin{aligned} \vec{a} &= \frac{(27.7\,\hat{\imath} + 16\,\hat{\jmath}) + (55\,\hat{\imath}) + (20.5\,\hat{\imath} - 35.5\,\hat{\jmath})}{120} \\ &= 0.86\,\hat{\imath} - 0.16\,\hat{\jmath} \quad \text{m/s}^2 \ . \end{aligned}$$

   (b) The magnitude of the acceleration vector is
$$|\vec{a}| = \sqrt{a_x^2 + a_y^2} = \sqrt{0.86^2 + (-0.16)^2} = 0.88 \text{ m/s}^2 \ .$$

   (c) The vector $\vec{a}$ makes an angle θ with the $+x$ axis, where
$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{-0.16}{0.86}\right) = -11^\circ \ .$$

7. We denote the two forces $\vec{F}_1$ and $\vec{F}_2$. According to Newton's second law, $\vec{F}_1 + \vec{F}_2 = m\vec{a}$, so $\vec{F}_2 = m\vec{a} - \vec{F}_1$.

   (a) In unit vector notation $\vec{F}_1 = (20.0\,\text{N})\hat{\imath}$ and
$$\vec{a} = -(12\sin 30^\circ \text{ m/s}^2)\hat{\imath} - (12\cos 30^\circ \text{ m/s}^2)\hat{\jmath} = -(6.0\,\text{m/s}^2)\hat{\imath} - (10.4\,\text{m/s}^2)\hat{\jmath} \ .$$
Therefore,
$$\begin{aligned} \vec{F}_2 &= (2.0\,\text{kg})\left(-6.0\,\text{m/s}^2\right)\hat{\imath} + (2.0\,\text{kg})\left(-10.4\,\text{m/s}^2\right)\hat{\jmath} - (20.0\,\text{N})\hat{\imath} \\ &= (-32\,\text{N})\hat{\imath} - (21\,\text{N})\hat{\jmath} \ . \end{aligned}$$

(b) The magnitude of $\vec{F}_2$ is

$$\left|\vec{F}_2\right| = \sqrt{F_{2x}^2 + F_{2y}^2} = \sqrt{(-32)^2 + (-21)^2} = 38 \text{ N} .$$

(c) The angle that $\vec{F}_2$ makes with the positive x axis is found from $\tan\theta = F_{2y}/F_{2x} = 21/32 = 0.656$. Consequently, the angle is either $33°$ or $33° + 180° = 213°$. Since both the x and y components are negative, the correct result is $213°$.

8. The goal is to arrive at the least magnitude of $\vec{F}_{\text{net}}$, and as long as the magnitudes of $\vec{F}_2$ and $\vec{F}_3$ are (in total) less than or equal to $|\vec{F}_1|$ then we should orient them opposite to the direction of $\vec{F}_1$ (which is the $+x$ direction).

(a) We orient both $\vec{F}_2$ and $\vec{F}_3$ in the $-x$ direction. Then, the magnitude of the net force is $50-30-20 = 0$, resulting in zero acceleration for the tire.

(b) We again orient $\vec{F}_2$ and $\vec{F}_3$ in the negative x direction. We obtain an acceleration along the $+x$ axis with magnitude

$$a = \frac{F_1 - F_2 - F_3}{m} = \frac{50\,\text{N} - 30\,\text{N} - 10\,\text{N}}{12\,\text{kg}} = 0.83 \text{ m/s}^2 .$$

(c) In this case, the forces $\vec{F}_2$ and $\vec{F}_3$ are collectively strong enough to have y components (one positive and one negative) which cancel each other and still have enough x contributions (in the $-x$ direction) to cancel $\vec{F}_1$. Since $|\vec{F}_2| = |\vec{F}_3|$, we see that the angle above the $-x$ axis to one of them should equal the angle below the $-x$ axis to the other one (we denote this angle θ). We require

$$\begin{aligned} -50\,\text{N} &= \vec{F}_{2x} + \vec{F}_{3x} \\ &= -(30\,\text{N})\cos\theta - (30\,\text{N})\cos\theta \end{aligned}$$

which leads to

$$\theta = \cos^{-1}\left(\frac{50\,\text{N}}{60\,\text{N}}\right) = 34° .$$

9. In all three cases 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. Its value is $(11.0\,\text{kg})(9.8\,\text{m/s}^2) = 108\,\text{N}$.

10. Three vertical forces are acting on the block: the earth pulls down on the block with gravitational force 3.0 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 N. There is no acceleration, so

$$\sum F_y = 0 = N + (1.0 \text{ N}) + (-3.0 \text{ N})$$

yields $N = 2.0$ N. By Newton's third law, the force exerted by the block on the surface has that same magnitude but opposite direction: 2.0 N down.

11. We apply Eq. 5-12.

(a) The mass is $m = W/g = (22\,\text{N})/(9.8\,\text{m/s}^2) = 2.2\,\text{kg}$. At a place where $g = 4.9\,\text{m/s}^2$, the mass is still 2.2 kg but the gravitational force is $F_g = mg = (2.2\,\text{kg})(4.9\,\text{m/s}^2) = 11\,\text{N}$.

(b) As noted, $m = 2.2$ kg.

(c) At a place where $g = 0$ the gravitational force is zero.

(d) The mass is still 2.2 kg.

12. We use $W_p = mg_p$, where W_p is the weight of an object of mass m on the surface of a certain planet p, and g_p is the acceleration of gravity on that planet.

   (a) The weight of the space ranger on Earth is $W_e = mg_e$ which we compute to be $(75\,\text{kg})\left(9.8\,\text{m/s}^2\right) = 7.4 \times 10^2\,\text{N}$.

   (b) The weight of the space ranger on Mars is $W_m = mg_m$ which we compute to be $(75\,\text{kg})(3.8\,\text{m/s}^2) = 2.9 \times 10^2\,\text{N}$.

   (c) The weight of the space ranger in interplanetary space is zero, where the effects of gravity are negligible.

   (d) The mass of the space ranger remains the same (75 kg) at all the locations.

13. According to Newton's second law, the magnitude of the force is given by $F = ma$, where a is the magnitude of the acceleration of the neutron. We use kinematics (Table 2-1) to find the acceleration that brings the neutron to rest in a distance d. Assuming the acceleration is constant, then $v^2 = v_0^2 + 2ad$ produces the value of a:

$$a = \frac{(v^2 - v_0^2)}{2d} = \frac{-(1.4 \times 10^7\,\text{m/s})^2}{2(1.0 \times 10^{-14}\,\text{m})} = -9.8 \times 10^{27}\,\text{m/s}^2 .$$

The magnitude of the force is consequently

$$F = m|a| = (1.67 \times 10^{-27}\,\text{kg})(9.8 \times 10^{27}\,\text{m/s}^2) = 16\ \text{N} .$$

14. The child-backpack is in static equilibrium while he waits, so Newton's second law applies with $\sum \vec{F} = 0$. Since students sometimes confuse this with Newton's third law, we phrase our results carefully.

   (a) The magnitude of the normal force $\vec{N}$ exerted upward by the sidewalk is equal, in this situation, to the total weight of the child-backpack, as a result of $\sum \vec{F} = 0$. Thus, $\vec{N} = (33.5\ \text{kg})(9.8\ \text{m/s}^2) = 328$ N and is directed up; this is $\vec{F}_{sc}$ – the force of the sidewalk exerted up on the child's feet. By Newton's third law, the force exerted down (at the child's feet) on the sidewalk is $\vec{F}_{cs} = 328$ N downward.

   (b) Except for an entirely negligible gravitation attraction between the child and the concrete, there is no force exerted on the sidewalk by the child when the child is not in contact with it.

   (c) Earth pulls gravitationally on the child, and the child pulls equally in the opposite direction on Earth. This force is the previously computed weight $(29.0)(9.8) = 284$ N. The gravitational force on Earth exerted by the child is 284 N up. But the contact force exerted by the child on the sidewalk (hence, on Earth) is (see part (a)) 328 N downward. Thus, the *net* force exerted by the child on Earth is zero.

   (d) Here the answer is simply the gravitational interaction: 284 N up.

15. We note that the free-body diagram is shown in Fig. 5-18 of the text.

   (a) Since the acceleration of the block is zero, the components of the Newton's second law equation yield $T - mg\sin\theta = 0$ and $N - mg\cos\theta = 0$. Solving the first equation for the tension in the string, we find
$$T = mg\sin\theta = (8.5\,\text{kg})(9.8\,\text{m/s}^2)\sin 30^\circ = 42\ \text{N} .$$

   (b) We solve the second equation in part (a) for the normal force N:
$$N = mg\cos\theta = (8.5\,\text{kg})(9.8\,\text{m/s}^2)\cos 30^\circ = 72\ \text{N} .$$

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

$$a = -g\sin\theta = -9.8\sin 30^\circ = -4.9$$

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

16. An excellent analysis of the accelerating elevator is given in Sample Problem 5-8 in the textbook.

(a) From Newton's second law

$$N - mg = ma \quad \text{where} \;\; a = a_{\text{max}} = 2.0 \text{ m/s}^2$$

we obtain $N = 590$ N upward, for $m = 50$ kg.

(b) Again, we use Newton's second law

$$N - mg = ma \quad \text{where} \;\; a = a_{\text{max}} = -3.0 \text{ m/s}^2 \; .$$

Now, we obtain $N = 340$ N upward.

(c) Returning to part (a), we use Newton's third law, and conclude that the force exerted by the passenger on the floor is $\vec{F}_{PF} = 590$ N downward.

17. (a) The acceleration is

$$a = \frac{F}{m} = \frac{20\,\text{N}}{900\,\text{kg}} = 0.022 \text{ m/s}^2 \; .$$

(b) The distance traveled in 1 day ($= 86400\,\text{s}$) is

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

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

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

18. 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 ($m = W/g = 8.7$ kg). Our $+x$ axis is in the direction of the salmon's velocity (away from the fisherman), so that its acceleration ("deceleration") is negative-valued and the force of tension is in the $-x$ direction: $\vec{T} = -T$. We use Eq. 2-16 and SI units (noting that $v = 0$).

$$v^2 = v_0^2 + 2a\Delta x \quad \Longrightarrow \quad a = -\frac{v_0^2}{2\Delta x} = -\frac{2.8^2}{2(0.11)}$$

which yields $a = -36$ m/s^2. Assuming there are no significant horizontal forces other than the tension, Eq. 5-1 leads to

$$\vec{T} = m\vec{a} \quad \Longrightarrow \quad -T = (8.7\,\text{kg})\left(-36\,\text{m/s}^2\right)$$

which results in $T = 3.1 \times 10^2$ N.

19. In terms of magnitudes, Newton's second law is $F = ma$, where F represents $|\vec{F}_{\text{net}}|$, a represents $|\vec{a}|$ (which it does not always do; note the use of a in the previous solution), and m is the (always positive) mass. The magnitude of the acceleration can be found using constant acceleration kinematics (Table 2-1). 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 $v = (1600\,\text{km/h})(1000\,\text{m/km})/(3600\,\text{s/h}) = 444\,\text{m/s}$, so

$$F = (500\,\text{kg})\frac{444\,\text{m/s}}{1.8\,\text{s}} = 1.2 \times 10^5\,\text{N} \; .$$

20. 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 car's velocity, so that its acceleration ("deceleration") is negative-valued and the stopping force is in the $-x$ direction: $\vec{F} = -F$.

    (a) We use Eq. 2-16 and SI units (noting that $v = 0$ and $v_0 = 40(1000/3600) = 11.1$ m/s).

    $$v^2 = v_0^2 + 2a\Delta x \implies a = -\frac{v_0^2}{2\Delta x} = -\frac{11.1^2}{2(15)}$$

    which yields $a = -4.12$ m/s^2. Assuming there are no significant horizontal forces other than the stopping force, Eq. 5-1 leads to

    $$\vec{F} = m\vec{a} \implies -F = (1327\,\text{kg})\left(-4.12\,\text{m/s}^2\right)$$

    which results in $F = 5.5 \times 10^3$ N.

    (b) Eq. 2-11 readily yields $t = -v_0/a = 2.7$ s.

    (c) Keeping F the same means keeping 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) Eq. 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 (c).

21. 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 and the $+y$ axis to be in the direction of the electrical force, and place the origin at the initial position of the electron. Since the force and acceleration are constant, we use the equations from Table 2-1: $x = v_0 t$ and

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

    The time taken by the electron to travel a distance x (= 30 mm) horizontally is $t = x/v_0$ and its deflection in the direction of the force is

    $$y = \frac{1}{2}\frac{F}{m}\left(\frac{x}{v_0}\right)^2 = \frac{1}{2}\left(\frac{4.5 \times 10^{-16}}{9.11 \times 10^{-31}}\right)\left(\frac{30 \times 10^{-3}}{1.2 \times 10^7}\right)^2 = 1.5 \times 10^{-3}\ \text{m} .$$

22. The stopping force $\vec{F}$ and the path of the passenger are horizontal. Our $+x$ axis is in the direction of the passenger's motion, so that the passenger's acceleration ("deceleration") is negative-valued and the stopping force is in the $-x$ direction: $\vec{F} = -F$. We use Eq. 2-16 and SI units (noting that $v = 0$ and $v_0 = 53(1000/3600) = 14.7$ m/s).

    $$v^2 = v_0^2 + 2a\Delta x \implies a = -\frac{v_0^2}{2\Delta x} = -\frac{14.7^2}{2(0.65)}$$

    which yields $a = -167$ m/s^2. Assuming there are no significant horizontal forces other than the stopping force, Eq. 5-1 leads to

    $$\vec{F} = m\vec{a} \implies -F = (41\,\text{kg})\left(-167\,\text{m/s}^2\right)$$

    which results in $F = 6.8 \times 10^3$ N.

23. We note that The rope is 22° from vertical – and therefore 68° from horizontal.

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

$$\vec{T} = T\cos 68^\circ\,\hat{\imath} + T\sin 68^\circ\,\hat{\jmath} = 285\,\hat{\imath} + 705\,\hat{\jmath}$$

understood to be in newtons.

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

$$\vec{F}_{\text{net}} = \vec{T} + \vec{W} = 285\,\hat{\imath} + 705\,\hat{\jmath} - 820\,\hat{\jmath} = 285\,\hat{\imath} - 115\,\hat{\jmath}$$

again understood to be in newtons.

(c) In a manner that is efficiently implemented on a vector capable calculator, we convert from rectangular (x, y) components to magnitude-angle notation:

$$\vec{F}_{\text{net}} = (285, -115) \longrightarrow (307\ \angle - 22^\circ)$$

so that the net force has a magnitude of 307 N.

(d) The angle (see part (c)) has been found to be 22° below horizontal (away from cliff)

(e) Since $\vec{a} = \vec{F}_{\text{net}}\,/\,m$ where $m = W/g = 84$ kg, we obtain $\vec{a} = 3.67\ \text{m/s}^2$

(f) Eq. 5-1 requires that $\vec{a} \parallel \vec{F}_{\text{net}}$ so that it is also directed at 22° below horizontal (away from cliff).

24. The analysis of coordinates and forces (the free-body diagram) is exactly as in the textbook in Sample Problem 5-7 (see Fig. 5-18(b) and (c)).

(a) Constant velocity implies zero acceleration, so the "uphill" force must equal (in magnitude) the "downhill" force: $T = mg\sin\theta$. Thus, with $m = 50$ kg and $\theta = 8.0^\circ$, the tension in the rope equals 68 N.

(b) With an uphill acceleration of 0.10 m/s^2, Newton's second law (applied to the x axis shown in Fig. 5-18(b)) yields

$$T - mg\sin\theta = ma \implies T - (50)(9.8)\sin 8.0^\circ = (50)(0.10)$$

which leads to $T = 73$ N.

25. (a) Since friction is negligible the force of the girl is the only horizontal force 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

$$a_s = \frac{F}{m_s} = \frac{5.2\,\text{N}}{8.4\,\text{kg}} = 0.62\ \text{m/s}^2\ .$$

(b) According to Newton's third law, the force of the sled on the girl is also 5.2 N. Her acceleration is

$$a_g = \frac{F}{m_g} = \frac{5.2\,\text{N}}{40\,\text{kg}} = 0.13\ \text{m/s}^2\ .$$

(c) The accelerations of the sled and girl are in opposite directions. Assuming the girl starts at the origin and moves in the $+x$ direction, her coordinate is given by $x_g = \frac{1}{2}a_g t^2$. The sled starts at $x_0 = 1.5$ m and moves in the $-x$ direction. Its coordinate is given by $x_s = x_0 - \frac{1}{2}a_s t^2$. They meet when

$$\begin{aligned} x_g &= x_s \\ \frac{1}{2}a_g t^2 &= x_0 - \frac{1}{2}a_s t^2\ . \end{aligned}$$

This occurs at time

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

By then, the girl has gone the distance

$$x_g = \frac{1}{2}a_g t^2 = \frac{x_0 a_g}{a_g + a_s} = \frac{(15)(0.13)}{0.13 + 0.62} = 2.6 \text{ m} .$$

26. We assume the direction of motion is $+x$ and assume the refrigerator starts from rest (so that the speed being discussed is the velocity v which results from the process). The only force along the x axis is the x component of the applied force $\vec{F}$.

(a) Since $v_0 = 0$, the combination of Eq. 2-11 and Eq. 5-2 leads simply to

$$F_x = m\left(\frac{v}{t}\right) \implies v_i = \left(\frac{F\cos\theta_i}{m}\right)t$$

for $i = 1$ or 2 (where we denote $\theta_1 = 0$ and $\theta_2 = \theta$ for the two cases). Hence, we see that the ratio v_2 over v_1 is equal to $\cos\theta$.

(b) Since $v_0 = 0$, the combination of Eq. 2-16 and Eq. 5-2 leads to

$$F_x = m\left(\frac{v^2}{2\Delta x}\right) \implies v_i = \sqrt{2\left(\frac{F\cos\theta_i}{m}\right)\Delta x}$$

for $i = 1$ or 2 (again, $\theta_1 = 0$ and $\theta_2 = \theta$ is used for the two cases). In this scenario, we see that the ratio v_2 over v_1 is equal to $\sqrt{\cos\theta}$.

27. We choose up as the $+y$ direction, so $\vec{a} = -3.00 \text{ m/s}^2\,\hat{\jmath}$ (which, without the unit-vector, we denote as a since this is a 1-dimensional problem in which Table 2-1 applies). From Eq. 5-12, we obtain the firefighter's mass: $m = W/g = 72.7$ kg.

(a) We denote the force exerted by the pole on the firefighter $\vec{F}_{\text{f p}} = F\,\hat{\jmath}$ and apply Eq. 5-1 (using SI units).

$$\begin{aligned} \vec{F}_{\text{net}} &= m\vec{a} \\ F - F_g &= ma \\ F - 712 &= (72.7)(-3.00) \end{aligned}$$

which yields $F = 494$ N. The fact that the result is positive means $\vec{F}_{\text{f p}}$ points up.

(b) Newton's third law indicates $\vec{F}_{\text{f p}} = -\vec{F}_{\text{p f}}$, which leads to the conclusion that $\vec{F}_{\text{p f}} = 494$ N down.

28. The coordinate choices are made in the problem statement.

(a) We write the velocity of the armadillo as $\vec{v} = v_x\,\hat{\imath} + v_y\,\hat{\jmath}$. Since there is no net force exerted on it in the x direction, the x component of the velocity of the armadillo is a constant: $v_x = 5.0$ m/s. In the y direction at $t = 3.0$ s, we have (using Eq. 2-11 with $v_{0\,y} = 0$)

$$v_y = v_{0\,y} + a_y t = v_{0\,y} + \left(\frac{F_y}{m}\right)t = \left(\frac{17}{12}\right)(3.0) = 4.3$$

in SI units. Thus

$$\vec{v} = 5.0\,\hat{\imath} + 4.3\,\hat{\jmath} \quad \text{m/s} .$$

(b) We write the position vector of the armadillo as $\vec{r} = r_x\,\hat{\imath} + r_y\,\hat{\jmath}$. At $t = 3.0$ s we have $r_x = (5.0)(3.0) = 15$ and (using Eq. 2-15 with $v_{0\,y} = 0$)

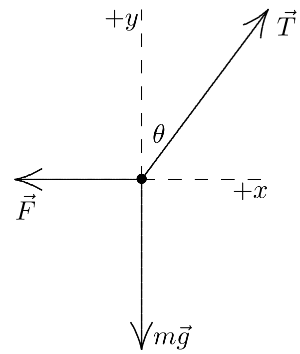
$$r_y = v_{0\,y}\,t + \frac{1}{2}a_y t^2 = \frac{1}{2}\left(\frac{F_y}{m}\right)t^2 = \frac{1}{2}\left(\frac{17}{12}\right)(3.0)^2 = 6.4$$

in SI units. The position vector at $t = 3.0$ s is therefore

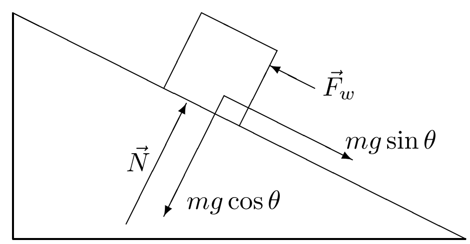
$$\vec{r} = 15\,\hat{\imath} + 6.4\,\hat{\jmath} \quad \text{m} .$$

29. 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. The x component of the net force is $T\sin\theta - F$ and the y component is $T\cos\theta - mg$, where $\theta = 37°$.

Since the sphere is motionless the net force on it is zero. We answer the questions in the reverse order. Solving $T\cos\theta - mg = 0$ for the tension, we obtain $T = mg/\cos\theta = (3.0\times10^{-4})(9.8)/\cos 37° = 3.7\times10^{-3}$ N. Solving $T\sin\theta - F = 0$ for the force of the air: $F = T\sin\theta = (3.7\times10^{-3})\sin 37° = 2.2\times10^{-3}$ N.



30. We label the 40 kg skier "m" which is represented as a block in the figure shown. The force of the wind is denoted $\vec{F}_w$ and might be either "uphill" or "downhill" (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 Newton's second law along the x axis leads to

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

This yields $F_w = 68$ N (uphill).

(b) Given our coordinate choice, we have $a = +1.0\ \text{m/s}^2$. Newton's second law

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

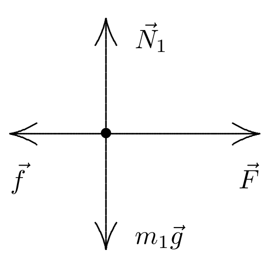
now leads to $F_w = 28$ N (uphill).

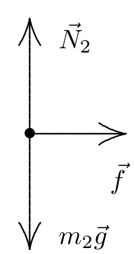
(c) Continuing with the forces as shown in our figure, the equation

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

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

31. The free-body diagrams for part (a) are shown below. $\vec{F}$ is the applied force and $\vec{f}$ 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 the force $-\vec{f}$ on block 1 (taking Newton's third law into account).





(a) Newton's second law for block 1 is $F - f = m_1 a$, where a is the acceleration. The second law for block 2 is $f = m_2 a$. Since the blocks move together they have the same acceleration and the same symbol is used in both equations. From the second equation we obtain the expression $a = f/m_2$, which we substitute into the first equation to get $F - f = m_1 f/m_2$. Therefore,

$$f = \frac{Fm_2}{m_1 + m_2} = \frac{(3.2\,\text{N})(1.2\,\text{kg})}{2.3\,\text{kg} + 1.2\,\text{kg}} = 1.1\,\text{N} .$$

(b) If $\vec{F}$ is applied to block 2 instead of block 1 (and in the opposite direction), the force of contact between the blocks is

$$f = \frac{Fm_1}{m_1 + m_2} = \frac{(3.2\,\text{N})(2.3\,\text{kg})}{2.3\,\text{kg} + 1.2\,\text{kg}} = 2.1\,\text{N} .$$

(c) We note that the acceleration of the blocks is the same in the two cases. In part (a), the force f is the only horizontal force on the block of mass m_2 and in part (b) f is the only horizontal force on the block with $m_1 > m_2$. Since $f = m_2 a$ in part (a) and $f = m_1 a$ in part (b), then for the accelerations to be the same, f must be larger in part (b).

32. The additional "apparent weight" experienced during upward acceleration is well treated in Sample Problem 5-8. The discussion in the textbook surrounding Eq. 5-13 is also relevant to this.

(a) When $\vec{F}_{\text{net}} = 3F - mg = 0$, we have

$$F = \frac{1}{3}mg = \frac{1}{3}(1400\,\text{kg})\left(9.8\,\text{m/s}^2\right) = 4.6 \times 10^3\ \text{N}$$

for the force exerted by each bolt on the engine.

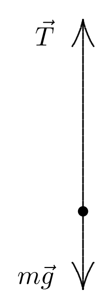
(b) The force on each bolt now satisfies $3F - mg = ma$, which yields

$$F = \frac{1}{3}m(g + a) = \frac{1}{3}(1400)(9.8 + 2.6) = 5.8 \times 10^3\ \text{N} .$$

33. The free-body diagram is shown below. $\vec{T}$ is the tension of the cable and $m\vec{g}$ is the force of gravity. If the upward direction is positive, then Newton's second law is $T - mg = ma$, where a is the acceleration.

Thus, the tension is $T = m(g + a)$. We use constant acceleration kinematics (Table 2-1) to find the acceleration (where $v = 0$ is the final velocity, $v_0 = -12\,\text{m/s}$ is the initial velocity, and $y = -42\,\text{m}$ is the coordinate at the stopping point). Consequently, $v^2 = v_0^2 + 2ay$ leads to $a = -v_0^2/2y = -(-12)^2/2(-42) = 1.71\,\text{m/s}^2$. We now return to calculate the tension:

$$\begin{aligned} T &= m(g + a) \\ &= (1600\,\text{kg})(9.8\,\text{m/s}^2 + 1.71\,\text{m/s}^2) \\ &= 1.8 \times 10^4\ \text{N} . \end{aligned}$$



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

$$\begin{aligned} F_{\text{net}} &= (m_1 + m_2 + m_3 + m_4)a \\ 222\,\text{N} &= (20\,\text{kg} + 15\,\text{kg} + m_3 + 12\,\text{kg})a . \end{aligned}$$

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

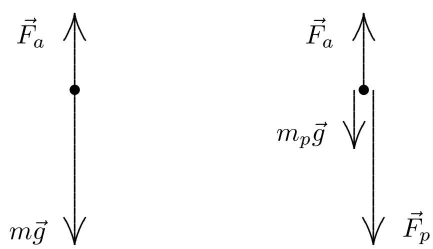
$$\begin{aligned} F'_{\text{net}} &= (m_3 + m_4)a \\ 111\,\text{N} &= (m_3 + 12\,\text{kg})a \ . \end{aligned}$$

We solve these two equations for m_3 to obtain $m_3 = 23\,\text{kg}$. The solution step can be made a little easier, though, by noting that the net force on penguins 1 and 2 is also 111 N and applying Newton's law to them as a single system to solve first for a.

35. We take the down to be the $+y$ direction.

(a) The first diagram (below) is the free-body diagram for the person and parachute, considered as a single object with a mass of $80\,\text{kg} + 5\,\text{kg} = 85\,\text{kg}$. $\vec{F}_a$ is the force of the air on the parachute and $m\vec{g}$ is the force of gravity. Application of Newton's second law produces $mg - F_a = ma$, where a is the acceleration. Solving for F_a we find

$$F_a = m(g - a) = (85\,\text{kg})(9.8\,\text{m/s}^2 - 2.5\,\text{m/s}^2) = 620\ \text{N} \ .$$



(b) The second diagram (above) is the free-body diagram for the parachute alone. $\vec{F}_a$ is the force of the air, $m_p\vec{g}$ is the force of gravity, and $\vec{F}_p$ is the force of the person. Now, Newton's second law leads to $m_p g + F_p - F_a = m_p a$. Solving for F_p, we obtain

$$F_p = m_p(a - g) + F_a = (5.0)(2.5 - 9.8) + 620 = 580\ \text{N} \ .$$

36. We apply Newton's second law first to the three blocks as a single system and then to the individual blocks. The $+x$ direction is to the right in Fig. 5-37.

(a) With $m_{\text{sys}} = m_1 + m_2 + m_3 = 67.0$ kg, we apply Eq. 5-2 to the x motion of the system – in which case, there is only one force $\vec{T}_3 = +T_3\,\hat{\imath}$.

$$\begin{aligned} T_3 &= m_{\text{sys}}\, a \\ 65.0\,\text{N} &= (67.0\,\text{kg})a \end{aligned}$$

which yields $a = 0.970\ \text{m/s}^2$ for the system (and for each of the blocks individually).

(b) Applying Eq. 5-2 to block 1, we find

$$T_1 = m_1 a = (12.0\,\text{kg})\left(0.970\ \text{m/s}^2\right) = 11.6\ \text{N} \ .$$

(c) In order to find T_2, we can either analyze the forces on block 3 or we can treat blocks 1 and 2 as a system and examine its forces. We choose the latter.

$$T_2 = (m_1 + m_2)\, a = (12.0 + 24.0)(0.970) = 34.9\ \text{N} \ .$$

37. We use the notation g as the acceleration due to gravity near the surface of Callisto, m as the mass of the landing craft, a as the acceleration of the landing craft, and F as the rocket thrust. We take down to be the positive direction. Thus, Newton's second law takes the form $mg - F = ma$. If the thrust is F_1 ($= 3260\,\text{N}$), then the acceleration is zero, so $mg - F_1 = 0$. If the thrust is F_2 ($= 2200\,\text{N}$), then the acceleration is a_2 ($= 0.39\,\text{m/s}^2$), so $mg - F_2 = ma_2$.

(a) The first equation gives the weight of the landing craft: $mg = F_1 = 3260\,\text{N}$.

(b) The second equation gives the mass:

$$m = \frac{mg - F_2}{a_2} = \frac{3260\,\text{N} - 2200\,\text{N}}{0.39\,\text{m/s}^2} = 2.7 \times 10^3 \text{ kg} .$$

(c) The weight divided by the mass gives the acceleration due to gravity: $g = (3260\,\text{N})/(2.7 \times 10^3\,\text{kg}) = 1.2\,\text{m/s}^2$.

38. Although the full specification of $\vec{F}_{\text{net}} = m\vec{a}$ in this situation involves both x and y axes, only the x-application is needed to find what this particular problem asks for. We note that $a_y = 0$ so that there is no ambiguity denoting a_x simply as a. We choose $+x$ to the right and $+y$ up, in Fig. 5-38. We also note that the x component of the rope's tension (acting on the crate) is $T_x = +450\cos 38° = 355$ N, and the resistive force (pointing in the $-x$ direction) has magnitude $f = 125$ N.

(a) Newton's second law leads to

$$T_x - f = ma \implies a = \frac{355 - 125}{310} = 0.74 \text{ m/s}^2 .$$

(b) In this case, we use Eq. 5-12 to find the mass: $m = W/g = 31.6$ kg. Now, Newton's second law leads to

$$T_x - f = ma \implies a = \frac{355 - 125}{31.6} = 7.3 \text{ m/s}^2 .$$

39. The force diagrams in Fig. 5-18 are helpful to refer to. In adapting Fig. 5-18(b) to this problem, the normal force $\vec{N}$ and the tension $\vec{T}$ should be labeled $F_{\text{m,r}_y}$ and $F_{\text{m,r}_x}$, respectively, and thought of as the y and x components of the force $\vec{F}_{\text{m,r}}$ exerted by the motorcycle on the rider. We adopt the coordinates used in Fig. 5-18 and note that they are not the usual horizontal and vertical axes.

(a) Since the net force equals ma, then the magnitude of the net force on the rider is $(60.0\,\text{kg})(3.0\,\text{m/s}^2) = 1.8 \times 10^2$ N.

(b) We apply Newton's second law to the x axis:

$$F_{\text{m,r}_x} - mg\sin\theta = ma$$

where $m = 60.0$ kg, $a = 3.0$ m/s^2, and $\theta = 10°$. Thus, $F_{\text{m,r}_x} = 282$ N. Applying it to the y axis (where there is no acceleration), we have

$$F_{\text{m,r}_y} - mg\cos\theta = 0$$

which produces $F_{\text{m,r}_y} = 579$ N. Using the Pythagorean theorem, we find

$$\sqrt{F_{\text{m,r}_x}^2 + F_{\text{m,r}_y}^2} = 644 \text{ N} .$$

Now, the magnitude of the force exerted on the rider by the motorcycle is the same magnitude of force exerted by the rider on the motorcycle, so the answer is 6.4×10^2 N.

40. Referring to Fig. 5-10(c) is helpful. In this case, 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 Newton's law to each mass). We take *down* as positive for the man's motion and *up* as positive for the sandbag's motion and, without ambiguity, denote their acceleration as a. The net force on the system is the difference between the weight of the man and that of the sandbag. The system mass is $m_{\text{sys}} = 85 + 65 = 150$ kg. Thus, Eq. 5-1 leads to

$$(85)(9.8) - (65)(9.8) = m_{\text{sys}}\, a$$

which yields $a = 1.3$ m/s^2. Since the system starts from rest, Eq. 2-16 determines the speed (after traveling $\Delta y = 10$ m) as follows:

$$v = \sqrt{2a\Delta y} = \sqrt{2(1.3)(10)} = 5.1 \text{ m/s} .$$

41. (a) The links are numbered from bottom to top. The forces on the bottom link are the force of gravity $m\vec{g}$, downward, and the force $\vec{F}_{2\text{on}1}$ of link 2, upward. Take the positive direction to be upward. Then Newton's second law for this link is $F_{2\text{on}1} - mg = ma$. Thus $F_{2\text{on}1} = m(a+g) = (0.100\,\text{kg})(2.50\,\text{m/s}^2 + 9.8\,\text{m/s}^2) = 1.23\,\text{N}$.

(b) The forces on the second link are the force of gravity $m\vec{g}$, downward, the force $\vec{F}_{1\text{on}2}$ of link 1, downward, and the force $\vec{F}_{3\text{on}2}$ of link 3, upward. According to Newton's third law $\vec{F}_{1\text{on}2}$ has the same magnitude as $\vec{F}_{2\text{on}1}$. Newton's second law for the second link is $F_{3\text{on}2} - F_{1\text{on}2} - mg = ma$, so $F_{3\text{on}2} = m(a+g) + F_{1\text{on}2} = (0.100\,\text{kg})(2.50\,\text{m/s}^2 + 9.8\,\text{m/s}^2) + 1.23\,\text{N} = 2.46\,\text{N}$.

(c) Newton's second for link 3 is $F_{4\text{on}3} - F_{2\text{on}3} - mg = ma$, so $F_{4\text{on}3} = m(a+g) + F_{2\text{on}3} = (0.100\,\text{N})(2.50\,\text{m/s}^2 + 9.8\,\text{m/s}^2) + 2.46\,\text{N} = 3.69\,\text{N}$, where Newton's third law implies $F_{2\text{on}3} = F_{3\text{on}2}$ (since these are magnitudes of the force vectors).

(d) Newton's second law for link 4 is $F_{5\text{on}4} - F_{3\text{on}4} - mg = ma$, so $F_{5\text{on}4} = m(a+g) + F_{3\text{on}4} = (0.100\,\text{kg})(2.50\,\text{m/s}^2 + 9.8\,\text{m/s}^2) + 3.69\,\text{N} = 4.92\,\text{N}$, where Newton's third law implies $F_{3\text{on}4} = F_{4\text{on}3}$.

(e) Newton's second law for the top link is $F - F_{4\text{on}5} - mg = ma$, so $F = m(a+g) + F_{4\text{on}5} = (0.100\,\text{kg})(2.50\,\text{m/s}^2 + 9.8\,\text{m/s}^2) + 4.92\,\text{N} = 6.15\,\text{N}$, where $F_{4\text{on}5} = F_{5\text{on}4}$ by Newton's third law.

(f) Each link has the same mass and the same acceleration, so the same net force acts on each of them: $F_{\text{net}} = ma = (0.100\,\text{kg})(2.50\,\text{m/s}^2) = 0.25\,\text{N}$.

42. The mass of the jet is $m = W/g = 2.36 \times 10^4$ kg. Its acceleration is found from Eq. 2-16:

$$v^2 = v_0^2 + 2a\Delta x \implies a = \frac{85^2}{2(90)} = 40 \text{ m/s}^2 .$$

Thus, Newton's second law provides the needed force F from the catapult.

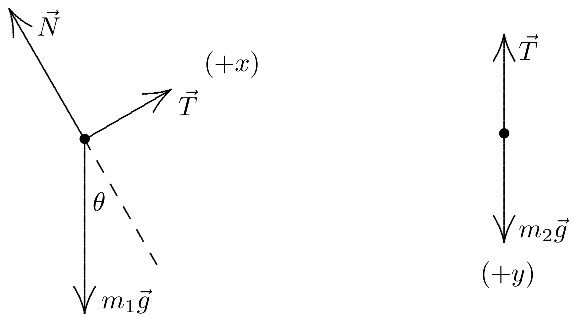
$$F + F_{\text{thrust}} = ma \implies F = \left(2.36 \times 10^4\right)(40) - 107 \times 10^3$$

which yields $F = 8.4 \times 10^5$ N.

43. The free-body diagram for each block is shown below. 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 $\vec{N}$ 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 Newton's second law to the x and y axes for block 1 and to the y axis of block 2, we obtain

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

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).



(a) We add the first and third equations above: $m_2g - m_1g\sin\theta = m_1a + m_2a$. Consequently, we find

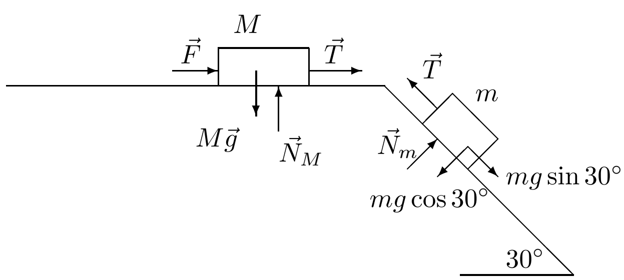
$$a = \frac{(m_2 - m_1\sin\theta)g}{m_1 + m_2} = \frac{(2.30\,\text{kg}) - 3.70\sin 30.0°)\,(9.8)}{3.70 + 2.30} = 0.735\ \text{m/s}^2\ .$$

(b) The result for a is positive, indicating that the acceleration of block 1 is indeed up the incline and that the acceleration of block 2 is vertically down.

(c) The tension in the cord is

$$T = m_1a + m_1g\sin\theta = (3.70)(0.735) + (3.70)(9.8)\sin 30° = 20.8\ \text{N}\ .$$

44. For convenience, we have labeled the 2.0 kg mass m and the 3.0 kg mass M. The $+x$ direction for m is "downhill" and the $+x$ direction for M is rightward; thus, they accelerate with the same sign.



(a) We apply Newton's second law to each block's x axis:

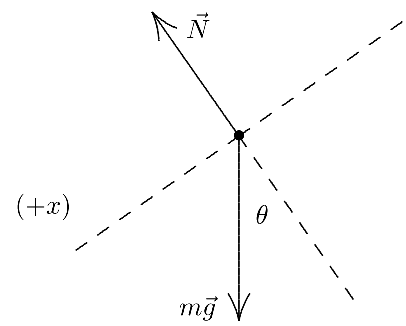
$$\begin{aligned} mg\sin 30° - T &= ma \\ F + T &= Ma \end{aligned}$$

Adding the two equations allows us to solve for the acceleration. With $F = 2.3$ N, we have $a = 1.8\ \text{m/s}^2$. We plug back in to find the tension $T = 3.1$ N.

(b) We consider the "critical" 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, $a = 4.9\ \text{m/s}^2$. This implies (along with $T = 0$ in the second equation in part (a)) that $F = (3.0)(4.9) = 14.7$ N in the critical case.

45. The free-body diagram is shown below. $\vec{N}$ 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 down the incline, in the direction of the acceleration, and the $+y$ direction to be in the direction of the normal force exerted by the incline on the block. The x component of Newton's second law is then $mg\sin\theta = ma$; thus, the acceleration is $a = g\sin\theta$.



(a) Placing the origin at the bottom of the plane, the kinematic equations (Table 2-1) for motion along the x axis which 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 $t = -v_0/a$. The position where it stops is

$$\begin{aligned} x &= -\frac{1}{2}\frac{v_0^2}{a} \\ &= -\frac{1}{2}\left(\frac{(-3.50\,\mathrm{m/s})^2}{(9.8\,\mathrm{m/s^2})\sin 32.0^\circ}\right) \\ &= -1.18\ \mathrm{m}\ . \end{aligned}$$

(b) The time is

$$t = -\frac{v_0}{a} = -\frac{v_0}{g\sin\theta} = -\frac{-3.50\,\mathrm{m/s}}{(9.8\,\mathrm{m/s^2})\sin 32.0^\circ} = 0.674\ \mathrm{s}\ .$$

(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

$$t = -\frac{2v_0}{a} = -\frac{2v_0}{g\sin\theta} = -\frac{2(-3.50\,\mathrm{m/s})}{(9.8\,\mathrm{m/s^2})\sin 32.0^\circ} = 1.35\,\mathrm{s}\ .$$

The velocity when it returns is therefore

$$v = v_0 + at = v_0 + gt\sin\theta = -3.50 + (9.8)(1.35)\sin 32^\circ = 3.50\ \mathrm{m/s}\ .$$

46. We write the length unit light-month as c·month in this solution.

(a) The magnitude of the required acceleration is given by

$$a = \frac{\Delta v}{\Delta t} = \frac{(0.10)(3.0\times 10^8\,\mathrm{m/s})}{(3.0\,\mathrm{days})(86400\,\mathrm{s/day})} = 1.2\times 10^2\ \mathrm{m/s^2}\ .$$

(b) The acceleration in terms of g is

$$a = \left(\frac{a}{g}\right)g = \left(\frac{1.2\times 10^2\,\mathrm{m/s^2}}{9.8\,\mathrm{m/s^2}}\right)g = 12g\ .$$

(c) The force needed is

$$F = ma = \left(1.20\times 10^6\right)\left(1.2\times 10^2\right) = 1.4\times 10^8\ \mathrm{N}\ .$$

(d) The spaceship will travel a distance $d = 0.1$ c·month during one month. The time it takes for the spaceship to travel at constant speed for 5.0 light-months is

$$t = \frac{d}{v} = \frac{5.0\,\mathrm{c}\cdot\mathrm{months}}{0.1c} = 50 \text{ months}$$

which is about 4.2 years.

47. We take $+y$ to be up for both the monkey and the package.

(a) The force the monkey pulls downward on the rope has magnitude F. According to Newton's third law, the rope pulls upward on the monkey with a force of the same magnitude, so Newton's 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 Newton's second law for the package is $F + N - m_p g = m_p a_p$, where m_p is the mass of the package, a_p is its acceleration, and N is the normal force exerted by the ground on it. Now, if F is the minimum force required to lift the package, then $N = 0$ and $a_p = 0$. According to the second law equation for the package, this means $F = m_p g$. Substituting $m_p g$ for F in the equation for the monkey, we solve for a_m:

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

(b) As discussed, Newton's 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

$$F = m_p(g + a_p) = m_p(g - a_m)$$

and substituting this result into the second equation, we solve for a_m:

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

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

(d) Solving the second law equation for the package, we obtain

$$F = m_p\,(g - a_m) = (15)(9.8 - 2.0) = 120 \text{ N} .$$

48. The direction of motion (the direction of the barge's acceleration) is $+\hat{\mathrm{i}}$, and $+\hat{\mathrm{j}}$ is chosen so that the pull $\vec{F}_{\mathrm{h}}$ 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

$$\begin{aligned} (7900\,\mathrm{N})\cos 18^\circ + F_x &= ma \\ (7900\,\mathrm{N})\sin 18^\circ + F_y &= 0 \end{aligned}$$

respectively. Plugging in $a = 0.12$ m/s^2 and $m = 9500$ kg, we obtain $F_x = 6.4 \times 10^3$ N and $F_y = -2.4 \times 10^3$ N. The magnitude of the force of the water is therefore

$$F_{\mathrm{water}} = \sqrt{F_x^2 + F_y^2} = 6.8 \times 10^3 \text{ N} .$$

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

$$\tan^{-1}\left(\frac{F_y}{F_x}\right) = -21^\circ \quad \text{or} \quad 159^\circ.$$

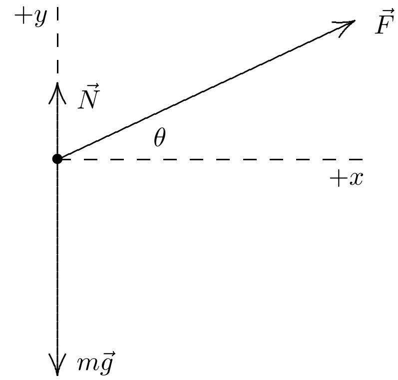
The signs of the components indicate the former is correct, so $\vec{F}_{\mathrm{water}}$ is at 21° measured clockwise from the line of motion.

49. The force diagram (not to scale) for the block is shown below. $\vec{N}$ 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 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 N (and if N is positive, then the assumption is true but if N is negative then the block leaves the floor). The y component of Newton's second law becomes $N + F\sin\theta - mg = 0$, so $N = mg - F\sin\theta = (5.00)(9.8) - (12.0)\sin 25.0° = 43.9\,\text{N}$. 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 $N = 0$ and the y component of the acceleration vanishes. The y component of the second law becomes $F\sin\theta - mg = 0$, so

$$F = \frac{mg}{\sin\theta} = \frac{(5.00)(9.8)}{\sin 25.0°} = 116\text{ N}\,.$$

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

$$a = \frac{F\cos\theta}{m} = \frac{116\cos 25°}{5.00} = 21.0\text{ m/s}^2\,.$$

50. 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, Newton's second law leads to

$$2T - mg = ma$$

so that when $a = 0$, the tension is $T = 466$ N.

(b) When $a = +1.3\text{ m/s}^2$ the equation in part (a) predicts that the tension will be $T = 527$ 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 Newton's second law now leads to

$$T - mg = ma$$

so that when $a = 0$, the tension is $T = 931$ N.

(d) When $a = +1.3\text{ m/s}^2$ the equation in part (c) predicts that the tension will be $T = 1.05 \times 10^3$ N.

(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 $2T = 931$ N.

(f) In part (b) the downward force on the ceiling has magnitude $2T = 1.05 \times 10^3$ N.

(g) In part (c) the downward force on the ceiling has magnitude $2T = 1.86 \times 10^3$ N.

(h) In part (d) the downward force on the ceiling has magnitude $2T = 2.11 \times 10^3$ N.

51. (a) A small segment of the rope has mass and is pulled down by the gravitational force of the Earth. Equilibrium is reached because neighboring portions of the rope pull up sufficiently on it. Since tension is a force *along* the rope, at least one of the neighboring portions must slope up away from the segment we are considering. Then, the tension has an upward component which means the rope sags.

(b) The only force acting with a horizontal component is the applied force $\vec{F}$. Treating the block and rope as a single object, we write Newton's second law for it: $F = (M + m)a$, where a is the acceleration and the positive direction is taken to be to the right. The acceleration is given by $a = F/(M + m)$.

(c) The force of the rope F_r is the only force with a horizontal component acting on the block. Then Newton's second law for the block gives

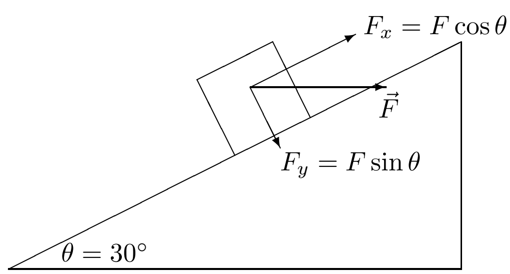
$$F_r = Ma = \frac{MF}{M + m}$$

where the expression found above for a has been used.

(d) Treating the block and half the rope as a single object, with mass $M + \frac{1}{2}m$, where the horizontal force on it is the tension T_m at the midpoint of the rope, we use Newton's second law:

$$T_m = (M + \frac{1}{2}m)a = \frac{(M + \frac{1}{2}m)F}{(M + m)} = \frac{(2M + m)F}{2(M + m)} \ .$$

52. The coordinate system we wish to use is shown in Fig. 5-18(c) in the textbook, so we resolve this horizontal force into appropriate components.



(a) Referring to Fig. 5-18 in the textbook, we see that Newton's second law applied to the x axis produces

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

For $a = 0$, this yields $F = 566$ N.

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

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

which yields the normal force $N = 1.13 \times 10^3$ N.

53. 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 (which is not its usual use in this chapter). When the mass is M (before the ballast is thrown out) the acceleration is downward and Newton's second law is $F_a - Mg = -Ma$. After the ballast is thrown out, the mass is $M - m$ (where m is the mass of the ballast) and the acceleration is upward. Newton's second law leads to

$F_a - (M - m)g = (M - m)a$. The earlier equation gives $F_a = M(g - a)$, and this plugs into the new equation to give

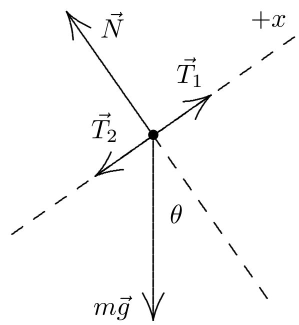
$$M(g-a) - (M-m)g = (M-m)a \implies m = \frac{2Ma}{g+a} .$$

54. The free-body diagram is shown below. Newton's 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:

$$\begin{aligned} T_1 - T_2 &= m(g\sin\theta + a) \\ &= (2800)\,(9.8\sin 35^\circ + 0.81) \\ &= 1.8 \times 10^4 \text{ N} . \end{aligned}$$



55. (a) The mass of the elevator is $m = 27800/9.8 = 2837$ kg and (with $+y$ upward) the acceleration is $a = +1.22$ m/s^2. Newton's second law leads to

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

which yields $T = 3.13 \times 10^4$ N for the tension.

(b) The term "deceleration" 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 $a = -1.22$ m/s^2, so that the tension $T = m(g + a)$ turns out to be $T = 2.43 \times 10^4$ N in this case.

56. (a) The term "deceleration" 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 $a = +2.4$ m/s^2. Newton's second law leads to

$$T - mg = ma \implies m = \frac{T}{g+a}$$

which yields $m = 7.3$ kg for the mass.

(b) Repeating the above computation (now to solve for the tension) with $a = +2.4$ m/s^2 will, of course, leads us right back to $T = 89$ N. Since the direction of the velocity did not enter our computation, this is to be expected.

57. The mass of the bundle is $m = 449/9.8 = 45.8$ kg and we choose $+y$ upward.

(a) Newton's second law, applied to the bundle, leads to

$$T - mg = ma \implies a = \frac{387 - 449}{45.8}$$

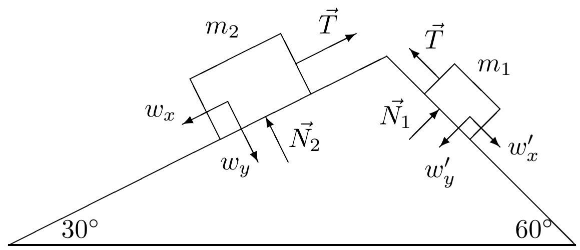
which yields $a = -1.35$ m/s^2 for the acceleration. The minus sign in the result indicates the acceleration vector points down. Any downward acceleration of magnitude greater than this is also acceptable (since that would lead to even smaller values of tension).

(b) We use Eq. 2-16 (with Δx replaced by $\Delta y = -6.1$ m). We assume $v_0 = 0$.

$$|v| = \sqrt{2a\Delta y} = \sqrt{2(-1.35)(-6.1)} = 4.1 \text{ m/s} .$$

For downward accelerations greater than 1.35 m/s^2, the speeds at impact will be larger than 4.1 m/s.

58. For convenience, we have labeled the 2.0 kg box m_1 and the 3.0 kg box m_2 – and their weights w' and w, respectively. The $+x$ axis is "downhill" for m_1 and "uphill" for m_2 (so they both accelerate with the same sign).



We apply Newton's second law to each box's x axis:

$$\begin{aligned} m_1 g \sin 60^\circ - T &= m_1 a \\ T - m_2 g \sin 30^\circ &= m_2 a \end{aligned}$$

Adding the two equations allows us to solve for the acceleration $a = 0.45$ m/s^2. This value is plugged back into either of the two equations to yield the tension $T = 16$ N.

59. (a) There are six legs, and the vertical component of the tension force in each leg is $T \sin\theta$ where $\theta = 40^\circ$. For vertical equilibrium (zero acceleration in the y direction) then Newton's second law leads to

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

which (expressed as a multiple of the bug's weight mg) gives roughly $0.26mg$ for the tension.

(b) The angle θ is measured from horizontal, so as the insect "straightens out the legs" 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.

60. (a) Choosing the direction of motion as $+x$, Eq. 2-11 gives

$$a = \frac{88.5\,\text{km/h} - 0}{6.0\,\text{s}} = 15 \text{ km/h/s} .$$

Converting to SI, this is $a = 4.1$ m/s^2.

(b) With mass $m = 2000/9.8 = 204$ kg, Newton's second law gives $\vec{F} = m\vec{a} = 836$ N in the $+x$ direction.

61. (a) Intuition readily leads to the conclusion (that the heavier block should be the hanging one, for largest acceleration). The force that "drives" the system into motion is the weight of the hanging block (gravity acting on the block on the table has no effect on the dynamics, so long as we ignore friction).

(b) In Sample Problem 5-5 (where it was assumed the m is the hanging block) Eq. 5-21 gave the acceleration. Now that we have switched $m \leftrightarrow M$ (so that now M is the hanging block) our new version of Eq. 5-21 is

$$a = \frac{M}{m+M}\, g = 6.5 \text{ m/s}^2 .$$

(c) Switching $m \leftrightarrow M$ has no effect on Eq. 5-22, which yields

$$T = \frac{mM}{m+M}\, g = 13 \text{ N} .$$

62. Making separate free-body diagrams for the helicopter and the truck, one finds there are two forces on the truck ($\vec{T}$ upward, caused by the tension, which we'll think of as that of a single cable, and $m\vec{g}$ downward, where $m = 4500$ kg) and three forces on the helicopter ($\vec{T}$ downward, $\vec{F}_{\text{lift}}$ upward, and $M\vec{g}$ downward, where $M = 15000$ kg). With $+y$ upward, then $a = +1.4$ m/s^2 for both the helicopter and the truck.

   (a) Newton's law applied to the helicopter and truck separately gives

$$\begin{aligned} F_{\text{lift}} - T - Mg &= Ma \\ T - mg &= ma \end{aligned}$$

   which we add together to obtain

$$F_{\text{lift}} - (M+m)g = (M+m)a \ .$$

   From this equation, we find $F_{\text{lift}} = 2.2 \times 10^5$ N.

   (b) From the truck equation $T - mg = ma$ we obtain $T = 5.0 \times 10^4$ N.

63. (a) With SI units understood, the net force is

$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 = (3.0 + (-2.0))\,\hat{\imath} + (4.0 + (-6.0))\,\hat{\jmath}$$

   which yields $\vec{F}_{\text{net}} = 1.0\,\hat{\imath} - 2.0\,\hat{\jmath}$ in Newtons.

   (b) Using magnitude-angle notation (especially convenient on a vector-capable calculator), the answer to part (a) becomes
   $\vec{F}_{\text{net}} = (2.2\,\text{N} \angle -63°)$.

   (c) Since $\vec{F}_{\text{net}}$ is equal to $\vec{a}$ multiplied by a positive scalar (which cannot affect the direction of the vector it multiplies), then the acceleration has the same angle as the net force. The magnitude of $\vec{a}$ comes from dividing the magnitude of $\vec{F}_{\text{net}}$ by the mass ($m = 1.0$ kg). Thus, in magnitude-angle notation, the answer is $\vec{a} = (2.2\,\text{m/s}^2 \angle -63°)$.

64. We take rightwards as the $+x$ direction. Thus, $\vec{F}_1 = 20\,\hat{\imath}$ in Newtons. 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 $\vec{a} = +10\,\hat{\imath}$ in SI units, then the equation above gives $\vec{F}_2 = 0$.

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

   (c) If $\vec{a} = 0$, then the equation gives $\vec{F}_2 = -20\,\hat{\imath}$ N.

   (d) If $\vec{a} = -10\,\hat{\imath}$ m/s^2, the equation gives $\vec{F}_2 = -40\,\hat{\imath}$ N.

   (e) If $\vec{a} = -20\,\hat{\imath}$ m/s^2, the equation gives $\vec{F}_2 = -60\,\hat{\imath}$ N.

65. (a) Since the performer's weight is $(52)(9.8) = 510$ N, the rope breaks.

   (b) Setting $T = 425$ N in Newton's second law (with $+y$ upward) leads to

$$T - mg = ma \quad \Longrightarrow \quad a = \frac{T}{m} - g$$

   which yields $|a| = 1.6$ m/s^2.

66. The mass of the pilot is $m = 735/9.8 = 75$ kg. Denoting the upward force exerted by the spaceship (his seat, presumably) on the pilot as $\vec{F}$ and choosing upward the $+y$ direction, then Newton's second law leads to

$$F - mg_{\text{moon}} = ma \quad \Longrightarrow \quad F = (75)(1.6 + 1.0) = 195 \text{ N} \ .$$

67. With SI units understood, the net force on the box is

$$\vec{F}_{\text{net}} = (3.0 + 14\cos 30^\circ - 11)\,\hat{\imath} + (14\sin 30^\circ + 5.0 - 17)\,\hat{\jmath}$$

which yields $\vec{F}_{\text{net}} = 4.1\,\hat{\imath} - 5.0\,\hat{\jmath}$ in Newtons.

(a) Newton's second law applied to the $m = 4.0$ kg box leads to

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m} = 1.0\,\hat{\imath} - 1.3\,\hat{\jmath} \ \text{m/s}^2 \ .$$

(b) The magnitude of $\vec{a}$ is $\sqrt{1.0^2 + (-1.3)^2} = 1.6$ m/s^2. Its angle is $\tan^{-1}(-1.3/1.0) = -50^\circ$ (that is, 50° measured clockwise from the rightward axis).

68. The net force is in the y direction, so the unknown force must have an x component that cancels the $(8.0\,\text{N})\hat{\imath}$ value of the known force, and it must also have enough y component to give the 3.0 kg object an acceleration of $(3.0\,\text{m/s}^2)\hat{\jmath}$. Thus, the magnitude of the unknown force is

$$\left|\vec{F}\right| = \sqrt{F_x^2 + F_y^2} = \sqrt{(-8.0)^2 + 9.0^2} = 12 \text{ N} \ .$$

69. We are only concerned with horizontal forces in this problem (gravity plays no direct role). Thus, $\sum \vec{F} = m\vec{a}$ reduces to $\vec{F}_{\text{avg}} = m\vec{a}$, and we see that the magnitude of the force is ma, where $m = 0.20$ kg and

$$a = |\vec{a}| = \sqrt{a_x^2 + a_y^2}$$

and the direction of the force is the same as that of $\vec{a}$. We take *east* as the $+x$ direction and *north* as $+y$. The acceleration is the *average* acceleration in the sense of Eq. 4-15.

(a) We find the (average) acceleration to be

$$\vec{a} = \frac{\vec{v} - \vec{v}_0}{\Delta t} = \frac{(-5.0\,\hat{\imath}) - (2.0\,\hat{\imath})}{0.50} = -14\,\hat{\imath} \ \text{m/s}^2 \ .$$

Thus, the magnitude of the force is $(0.20\,\text{kg})(14\,\text{m/s}^2) = 2.8\,\text{N}$ and its direction is $-\,\hat{\imath}$ which means *west* in this context.

(b) A computation similar to the one in part (a) yields the (average) acceleration with two components, which can be expressed various ways:

$$\vec{a} = -4.0\,\hat{\imath} - 10.0\,\hat{\jmath} \ \rightarrow \ (-4.0, -10.0) \ \rightarrow \ (10.8 \ \angle \ -112^\circ)$$

Therefore, the magnitude of the force is $(0.20 \text{ kg})(10.8 \text{ m/s}^2) = 2.2$ N and its direction is 112° clockwise from east – which means it is 22° west of south, stated more conventionally.

70. The "certain force" is denoted F is assumed to be the net force on the object when it gives m_1 an acceleration $a_1 = 12$ m/s^2 and when it gives m_2 an acceleration $a_2 = 3.3$ m/s^2. Thus, we substitute $m_1 = F/a_1$ and $m_2 = F/a_2$ in appropriate places during the following manipulations.

(a) Now we seek the acceleration a of an object of mass $m_2 - m_1$ when F is the net force on it. Thus,

$$a = \frac{F}{m_2 - m_1} = \frac{F}{(F/a_2) - (F/a_1)} = \frac{a_1 a_2}{a_1 - a_2}$$

which yields $a = 4.6$ m/s^2.

(b) Similarly for an object of mass $m_2 + m_1$:

$$a = \frac{F}{m_2 + m_1} = \frac{F}{(F/a_2) + (F/a_1)} = \frac{a_1 a_2}{a_1 + a_2}$$

which yields $a = 2.6$ m/s^2.

71. We mention that the textbook treats this particular arrangement of blocks and pulleys in extensive detail in Sample Problem 5-5. Using the usual coordinate system (*right* $= +x$ and *up* $= +y$) for both blocks has the important consequence that for the 3.0 kg block to have a positive acceleration ($a > 0$), block M must have a negative acceleration of the same magnitude ($-a$). Thus, applying Newton's second law to the two blocks, we have

$$\begin{aligned} T &= (3.0 \text{ kg}) \left(1.0 \text{ m/s}^2\right) && \text{along } x \text{ axis} \\ T - Mg &= M\left(-1.0 \text{ m/s}^2\right) && \text{along } y \text{ axis} . \end{aligned}$$

   (a) The first equation yields the tension $T = 3.0$ N.

   (b) The second equation yields the mass $M = 3.0/8.8 = 0.34$ kg.

72. We take $+x$ uphill for the $m = 1.0$ kg box and $+x$ rightward for the $M = 3.0$ kg box (so the accelerations of the two boxes have the same magnitude and the same sign). The uphill force on m is F and the downhill forces on it are T and $mg\sin\theta$, where $\theta = 37°$. The only horizontal force on M is the rightward-pointed tension. Applying Newton's second law to each box, we find

$$\begin{aligned} F - T - mg\sin\theta &= ma \\ T &= Ma \end{aligned}$$

which are added to obtain $F - mg\sin\theta = (m + M)a$. This yields the acceleration

$$a = \frac{12 - (1.0)(9.8)\sin 37°}{1.0 + 3.0} = 1.53 \text{ m/s}^2 .$$

Thus, the tension is $T = Ma = (3.0)(1.53) = 4.6$ N.

73. (a) With $v_0 = 0$, Eq. 2-16 leads to

$$a = \frac{v^2}{2\Delta x} = \frac{\left(6.0 \times 10^6 \text{ m/s}\right)^2}{2(0.015 \text{ m})}$$

   which yields 1.2×10^{15} m/s^2 for the acceleration. The force responsible for producing this acceleration is

$$F = ma = \left(9.11 \times 10^{-31} \text{ kg}\right)\left(1.2 \times 10^{15} \text{ m/s}^2\right) = 1.1 \times 10^{-15} \text{ N} .$$

   (b) The weight is $mg = 8.9 \times 10^{-30}$ N, many orders of magnitude smaller than the result of part (a). As a result, gravity plays a negligible role in most atomic and subatomic processes.

74. We denote the thrust as T and choose $+y$ upward. Newton's second law leads to

$$T - Mg = Ma \implies a = \frac{2.6 \times 10^5}{1.3 \times 10^4} - 9.8$$

which yields $a = 10$ m/s^2.

75. (a) The reaction force to $\vec{F}_{MW} = 180$ N west is, by Newton's third law, $\vec{F}_{WM} = 180$ N east.

   (b) Applying $\vec{F} = m\vec{a}$ to the woman gives an acceleration $a = 180/45 = 4.0 \text{ m/s}^2$, directed west.

   (c) Applying $\vec{F} = m\vec{a}$ to the man gives an acceleration $a = 180/90 = 2.0 \text{ m/s}^2$, directed east.

76. We note that $mg = (15)(9.8) = 147$ N.

   (a) The penguin's weight is $W = 147$ N.

   (b) The normal force exerted upward on the penguin by the scale is equal to the gravitational pull W on the penguin because the penguin is not accelerating. So, by Newton's second law, $N = W = 147$ N.

(c) The reading on the scale, by Newton's third law, is the reaction force to that found in part (b). Its magnitude is therefore the same: 147 N.

77. Sample Problem 5-8 has a good treatment of the forces in an elevator. We apply Newton's second law (with $+y$ up)

$$N - mg = ma$$

where $m = 100$ kg and a must be estimated from the graph (it is the instantaneous slope at the various moments).

(a) At $t = 1.8$ s, we estimate the slope to be $+1.0\,\text{m/s}^2$. Thus, Newton's law yields $N \approx 1100$ N (up).

(b) At $t = 4.4$ s, the slope is zero, so $N = 980$ N (up).

(c) At $t = 6.8$ s, we estimate the slope to be -1.7 m/s^2. Thus, Newton's law yields $N = 810$ N (up).

78. From the reading when the elevator was at rest, we know the mass of the object is $m = 65/9.8 = 6.6$ kg. We choose $+y$ upward and note there are two forces on the object: mg downward and T upward (in the cord that connects it to the balance; T is the reading on the scale by Newton's third law).

(a) "Upward at constant speed" means constant velocity, which means no acceleration. Thus, the situation is just as it was at rest: $T = 65$ N.

(b) The term "deceleration" is used when the acceleration vector points in the direction opposite to the velocity vector. We're told the velocity is upward, so the acceleration vector points downward ($a = -2.4$ m/s^2). Newton's second law gives

$$T - mg = ma \quad \Longrightarrow \quad T = (6.6)(9.8 - 2.4) = 49 \text{ N} .$$

79. Since $(x_0, y_0) = (0, 0)$ and $\vec{v}_0 = 6.0\,\hat{\imath}$, we have from Eq. 2-15

$$\begin{aligned} x &= (6.0)t + \frac{1}{2}a_x t^2 \\ y &= \frac{1}{2}a_y t^2 . \end{aligned}$$

These equations express uniform acceleration along each axis; the x axis points east and the y axis presumably points north (the assumption is that the figure shown in the problem is a view *from above*). Lengths are in meters, time is in seconds, and force is in newtons.

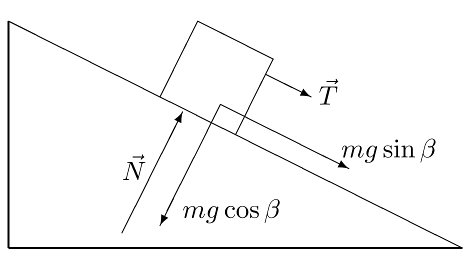
Examination of any non-zero (x, y) point will suffice, though it is certainly a good idea to check results by examining more than one. Here we will look at the $t = 4.0$ s point, at $(8.0, 8.0)$. The x equation becomes $8.0 = (6.0)(4.0) + \frac{1}{2}a_x(4.0)^2$. Therefore, $a_x = -2.0$ m/s^2. The y equation becomes $8.0 = \frac{1}{2}a_y(4.0)^2$. Thus, $a_y = 1.0$ m/s^2. The force, then, is

$$\vec{F} = m\vec{a} = -24\,\hat{\imath} + 12\,\hat{\jmath} \quad \longrightarrow \quad (27 \angle 153^\circ)$$

where the vector has been expressed in unit-vector and then magnitude-angle notation. Thus, the force has magnitude 27 N and is directed 63° west of north (or, equivalently, 27° north of west).

80. We label the 1.0 kg mass m and label the 2.0 kg mass M. We first analyze the forces on m.

The $+x$ direction



is "downhill"
(parallel to $\vec{T}$).

With the acceleration
($5.5\,\mathrm{m/s^2}$) in the positive x direction for m, then Newton's second law, applied to the x axis, becomes

$$T + mg\sin\beta = m(5.5\,\mathrm{m/s^2})$$

But for M, using the more familiar vertical y axis (with *up* as the positive direction), we have the acceleration in the negative direction:

$$F + T - Mg = M(-5.5\,\mathrm{m/s^2})$$

where the tension comes in as an upward force (the cord can pull, not push).

(a) From the equation for M, with $F = 6.0\,\mathrm{N}$, we find the tension $T = 2.6\,\mathrm{N}$.

(b) From the equation for m, using the result from part (a), we obtain the angle $\beta = 17°$.

81. (a) The bottom cord is only supporting a mass of 4.5 kg against gravity, so its tension is $(4.5)(9.8) = 44$ N.

(b) The top cord is supporting a total mass of 8.0 kg against gravity, so the tension there is $(8.0)(9.8) = 78$ N.

(c) In the second picture, the lowest cord supports a mass of 5.5 kg against gravity and consequently has a tension of $(5.5)(9.8) = 54$ N.

(d) The top cord, we are told, has tension 199 N which supports a total of $199/9.8 = 20.3$ kg, 10.3 of which is accounted for in the figure. Thus, the unknown mass in the middle must be $20.3 - 10.3 = 10.0$ kg, and the tension in the cord above it must be enough to support $10.0 + 5.5 = 15.5$ kg, so $T = (15.5)(9.8) = 152$ N. Another way to analyze this is to examine the forces on the 4.8 kg piece; one of the downward forces on it is this T.

82. The mass of the automobile is $17000/9.8 = 1735$ kg, so the net force has magnitude $F = (1735)(3.66) = 6.35 \times 10^2$ N.

83. (First problem in **Cluster 1**)

(a) Using the coordinate system and force resolution shown in the textbook Figure 5-18(c), we apply Newton's second law along the x axis

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

where $\theta = 30.0°$. Thus, $a = -4.9\,\mathrm{m/s^2}$. The magnitude of the acceleration, then, is $4.9\,\mathrm{m/s^2}$.

(b) Applying Newton's second law along the y axis (where there is no acceleration), we have

$$N - mg\cos\theta = 0 \ .$$

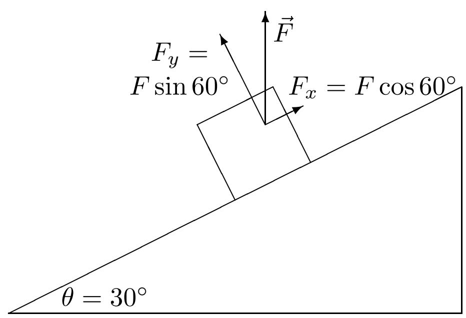
Thus, with $m = 10.0$ kg, we obtain $N = 84.9$ N.

84. (Second problem in **Cluster 1**)

(a) Newton's second law applied to the x axis yields $F - mg\sin\theta = ma$. Thus, with $F = 40.0$ N, we find $a = -0.90\ \mathrm{m/s^2}$. The interpretation is that the magnitude of the acceleration is $0.90\ \mathrm{m/s^2}$ and its direction is downhill.

(b) Substituting $F = 60.0$ N into $F - mg\sin\theta = ma$, we find $a = 1.1\ \mathrm{m/s^2}$. Thus, the acceleration is $1.1\ \mathrm{m/s^2}$ uphill.

85. (Third problem in **Cluster 1**)
The coordinate system we wish to use is shown in Figure 5-18(c) in the textbook, so we resolve this vertical force into appropriate components.



(a) Assuming the block is not pulled entirely off the incline, Newton's second law applied to the x axis yields

$$F_x - mg \sin\theta = ma \ .$$

This leads to $a = -1.9\,\text{m/s}^2$, which we interpret as a acceleration of $1.9\,\text{m/s}^2$ directed *downhill.*

(b) The assumption stated in part (a) implies there is no acceleration in the y direction. Newton's second law along the y axis gives

$$N + F_y - mg\cos\theta = 0 \ .$$

Therefore, $N = 32.9$ N. We note that a negative value of N would have been a sure sign that our assumption was incorrect.

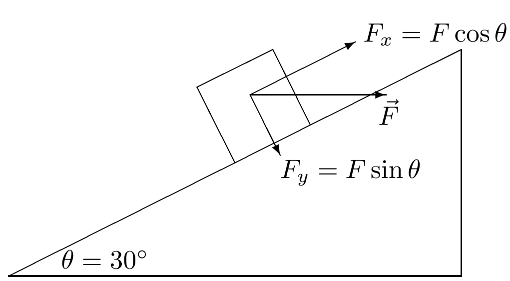
(c) The equation in part (a) can be used to solve for the equilibrium ($a = 0$) value of F:

$$F\cos 60° = mg\sin 30° = 49 \text{ N} \ .$$

Therefore, $F = 98$ N.

(d) There are three forces acting on the block: $\vec{N}, \vec{F}$, and $m\vec{g}$. Equilibrium generally suggests that the "vector triangle" formed by three such vectors closes on itself. In this case, however, two sides of that "triangle" are vertical! $\vec{F}$ is *up* and $m\vec{g}$ is *down*! The insight behind this "squashed triangle" is that $\vec{N}$ (the only vector that is not vertical) has zero magnitude. Thus, the block is not "bearing down" on the incline surface. In fact, in this circumstance, the incline is not needed at all for support; the value $F = 98.0$ N is just what is needed to hold the block (which weighs 98.0 N) aloft.

86. (Fourth problem in **Cluster 1**)
The coordinate system we wish to use is shown in Fig. 5-18 in the textbook, so we resolve this horizontal force into appropriate components.



(a) We apply Newton's second law to the x axis:

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

This yields $a = -1.44\,\mathrm{m/s^2}$, which is interpreted as an acceleration of $1.44\,\mathrm{m/s^2}$ downhill.

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

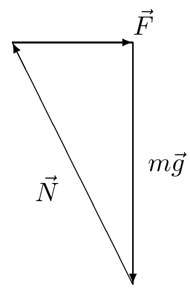
$$N - F_y - mg\cos\theta = 0\ .$$

This yields the normal force $N = 105$ N.

(c) When we set $a = 0$ in the part (a) equation, we obtain

$$F\cos 30^\circ = mg\sin 30^\circ\ .$$

Therefore, $F = 56.6$ N. Alternatively, we can use a "vector triangle" approach, referred to in the previous problem solution. We form a closed triangle.



We note that the angle between the weight vector and the normal force is θ. Thus, we see $mg\tan\theta = F$, which gives $F = 56.6$ N.