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

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

$$F_x = ma_x = ma \cos 20.0° = (1.00\,\text{kg})\left(2.00\,\text{m/s}^2\right) \cos 20.0° = 1.88\,\text{N}.$$

(b) The y component of the force is

$$F_y = ma_y = ma \sin 20.0° = (1.0\,\text{kg})\left(2.00\,\text{m/s}^2\right) \sin 20.0° = 0.684\,\text{N}.$$

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

$$\vec{F} = F_x\hat{\text{i}} + F_y\hat{\text{j}} = (1.88\text{ N})\hat{\text{i}} + (0.684\text{ N})\hat{\text{j}}\,.$$

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

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

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

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

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).

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

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

4. We note that $m\vec{a} = (-16\text{ N})\,\hat{\text{i}} + (12\text{ N})\,\hat{\text{j}}$. With the other forces as specified in the problem, then Newton's second law gives the third force as

$$\vec{F}_3 = m\vec{a} - \vec{F}_1 - \vec{F}_2 = (-34\text{ N})\,\hat{\text{i}} - (12\text{ N})\,\hat{\text{j}}.$$

5. 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 $\vec{F}_1 = (20.0 \text{ N})\hat{\text{i}}$ and

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

Therefore,

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

(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

$$\tan \theta = (F_{2y}/F_{2x}) = [(-20.8 \text{ N})/(-32.0 \text{ N})] = 0.656.$$

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 213°. An alternative answer is $213° - 360° = -147°$.

6. Since $\vec{v}$ = 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

$$\vec{F}_2 = -\vec{F}_1 = (-2\ \text{N})\,\hat{\text{i}} + (6\ \text{N})\,\hat{\text{j}} .$$

7. 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:

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

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

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

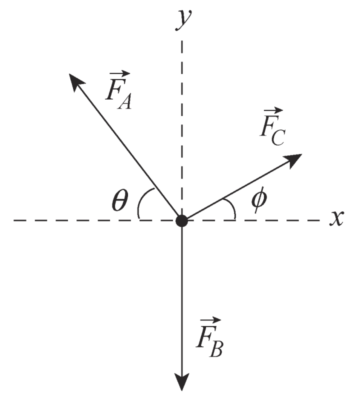
(b) The magnitude of the acceleration vector is

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

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

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

8. 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 $F_A = 220\ \text{N}$, $F_C = 170\ \text{N}$ and $\theta = 47°$, we get

$$\cos\phi = \frac{F_A \cos\theta}{F_C} = \frac{(220\ \text{N})\cos 47.0°}{170\ \text{N}} = 0.883 \quad \Rightarrow \ \phi = 28.0°$$

Substituting the value into the second force equation, we find

$$F_B = F_A \sin\theta + F_C \sin\phi = (220\ \text{N})\sin 47.0° + (170\ \text{N})\sin 28.0 = 241\ \text{N}.$$

9. The velocity is the derivative (with respect to time) of given function x, and the acceleration is the derivative of the velocity. Thus, $a = 2c - 3(2.0)(2.0)t$, which we use in Newton's second law: $F = (2.0 \text{ kg})a = 4.0c - 24t$ (with SI units understood). At $t = 3.0$ s, we are told that $F = -36$ N. Thus, $-36 = 4.0c - 24(3.0)$ can be used to solve for c. The result is $c = +9.0 \text{ m/s}^2$.

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 $t = 3.40$ s is

$$\vec{F} = m\frac{d^2x}{dt^2}\hat{\mathrm{i}} = (0.150)\left[8.00 - 18.0(3.40)\right]\hat{\mathrm{i}} = (-7.98\ \mathrm{N})\hat{\mathrm{i}}$$

11. To solve the problem, 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 via Newton's second law. Thus, differentiating $x(t) = -15.0 + 2.00t + 4.00t^3$ twice with respect to *t*, we get

$$\frac{dx}{dt} = 2.00 - 12.0t^2, \quad \frac{d^2x}{dt^2} = -24.0t$$

Similarly, differentiating $y(t) = 25.0 + 7.00t - 9.00t^2$ twice with respect to *t* yields

$$\frac{dy}{dt} = 7.00 - 18.0t, \quad \frac{d^2y}{dt^2} = -18.0$$

(a) The acceleration is

$$\vec{a} = a_x\hat{\text{i}} + a_y\hat{\text{j}} = \frac{d^2x}{dt^2}\hat{\text{i}} + \frac{d^2y}{dt^2}\hat{\text{j}} = (-24.0t)\hat{\text{i}} + (-18.0)\hat{\text{j}}.$$

At $t = 0.700\text{ s}$, we have $\vec{a} = (-16.8)\hat{\text{i}} + (-18.0)\hat{\text{j}}$ with a magnitude of

$$a = |\vec{a}| = \sqrt{(-16.8)^2 + (-18.0)^2} = 24.6\text{ m/s}^2.$$

Thus, the magnitude of the force is $F = ma = (0.34\text{ kg})(24.6\text{ m/s}^2) = 8.37\text{ N}$.

(b) The angle $\vec{F}$ or $\vec{a} = \vec{F}/m$ makes with $+x$ is

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{-18.0\text{ m/s}^2}{-16.8\text{ m/s}^2}\right) = 47.0° \text{ or } -133°.$$

We choose the latter ($-133°$) since $\vec{F}$ is in the third quadrant.

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

$$\vec{v}(t) = v_x\hat{\text{i}} + v_y\hat{\text{j}} = \frac{dx}{dt}\hat{\text{i}} + \frac{dy}{dt}\hat{\text{j}} = (2.00 - 12.0t^2)\hat{\text{i}} + (7.00 - 18.0t)\hat{\text{j}}.$$

At $t = 0.700\text{ s}$, we have $\vec{v}(t = 0.700\text{ s}) = (-3.88\text{ m/s})\hat{\text{i}} + (-5.60\text{ m/s})\hat{\text{j}}$. Therefore, the angle $\vec{v}$ makes with $+x$ is

$$\theta_v = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{-5.60\text{ m/s}}{-3.88\text{ m/s}}\right) = 55.3° \text{ or } -125°.$$

We choose the latter ($-125°$) since $\vec{v}$ is in the third quadrant.

12. From the slope of the graph we find $a_x = 3.0$ m/s^2. Applying Newton's 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. (a) – (c) 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 kg) (9.8 m/s^2) = 108 N.

14. 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 F_N. There is no acceleration, so

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

yields $F_N = 2.0$ N.

(a) By Newton's third law, the force exerted by the block on the surface has that same magnitude but opposite direction: 2.0 N.

(b) The direction is down.

15. (a) From the fact that $T_3 = 9.8$ N, we conclude the mass of disk D is 1.0 kg. Both this and that of disk C cause the tension $T_2 = 49$ N, which allows us to conclude that disk C has a mass of 4.0 kg. The weights of these two disks plus that of disk B determine the tension $T_1 = 58.8$ N, which leads to the conclusion that $m_B = 1.0$ kg. The weights of all the disks must add to the 98 N force described in the problem; therefore, disk A has mass 4.0 kg.

(b) $m_B = 1.0$ kg, as found in part (a).

(c) $m_C = 4.0$ kg, as found in part (a).

(d) $m_D = 1.0$ kg, as found in part (a).

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 Newton's second law leads to

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

which (expressed as a multiple of the bug's weight mg) gives roughly $T/mg \approx 0.26\,0$.

(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.

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

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

(b) Since the customer is being pulled down with an acceleration of $\vec{a}'_{\text{customer}} = 1.24\vec{g} = (-12.15\ \text{m/s}^2)\hat{\text{j}}$, the acceleration of the coin with respect to the customer is

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

(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

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

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

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

18. 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

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

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

$$\vec{F}_{\mathrm{net}} = \vec{T} + \vec{W} = (285\ \mathrm{N})\,\hat{\mathrm{i}} + (705\ \mathrm{N})\,\hat{\mathrm{j}} - (820\ \mathrm{N})\,\hat{\mathrm{j}} = (285\mathrm{N})\,\hat{\mathrm{i}} - (115\ \mathrm{N})\,\hat{\mathrm{j}}.$$

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

$$\vec{F}_{\mathrm{net}} = (285,\,-115) \rightarrow (307\angle -22.0°)$$

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

(d) The angle (see part (c)) has been found to be –22.0°, or 22.0° below horizontal (away from cliff).

(e) Since $\vec{a} = \vec{F}_{\mathrm{net}}/m$ where $m = W/g = 83.7$ kg, we obtain $\vec{a} = 3.67\ \mathrm{m/s^2}$.

(f) Eq. 5-1 requires that $\vec{a}\parallel\vec{F}_{\mathrm{net}}$ so that the angle is also –22.0°, or 22.0° below horizontal (away from cliff).

19. (a) Since the acceleration of the block is zero, the components of the Newton's second law equation yield

$$T - mg \sin \theta = 0$$
$$F_N - mg \cos \theta = 0.$$

Solving the first equation for the tension in the string, we find

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

(b) We solve the second equation in part (a) 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 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

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

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

20. We take rightwards as the $+x$ direction. Thus, $\vec{F}_1 = (20\ \text{N})\hat{\text{i}}$. 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 $\vec{a} = (+10\ \text{m/s}^2)\ \hat{\text{i}}$, then the equation above gives $\vec{F}_2 = 0$.

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

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

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

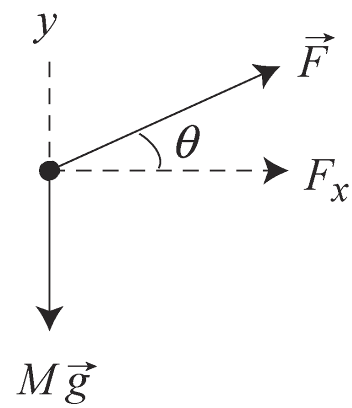
(e) If $\vec{a} = (-20\ \text{m/s}^2)\ \hat{\text{i}},$ the equation gives $\vec{F}_2 = (-60\,\text{N})\,\hat{\text{i}}.$

21. (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 = –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:

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

22. 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 Newton's 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

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

23. (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 s) is

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

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

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

24. 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 $v = 0$).

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

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

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

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

25. In terms of magnitudes, Newton's second law is $F = ma$, where $F = \left|\vec{F}_{\text{net}}\right|$, $a = |\vec{a}|$, 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

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

26. 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: $\vec{F} = -F\,\hat{\mathrm{i}}$. Using Eq. 2-16 with

$$v_0 = (53 \text{ km/h})(1000 \text{ m/km})/(3600 \text{ s/h}) = 14.7 \text{ m/s}$$

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

$$v^2 = v_0^2 + 2a\Delta x \;\;\Rightarrow\;\; a = -\frac{v_0^2}{2\Delta x} = -\frac{(14.7 \text{ m/s})^2}{2(0.65 \text{ m})} = -167 \text{ m/s}^2 .$$

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

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

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

27. We choose up as the $+y$ direction, so $\vec{a} = (-3.00\,\text{m/s}^2)\hat{\text{j}}$ (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 $\vec{F}_{\text{fp}} = F_{\text{fp}}\,\hat{\text{j}}$ and apply Eq. 5-1. Since $\vec{F}_{\text{net}} = m\vec{a}$, we have

$$F_{\text{fp}} - F_g = ma \quad \Rightarrow \; F_{\text{fp}} - 712\text{ N} = (72.7\text{ kg})(-3.00\text{ m/s}^2)$$

which yields $F_{\text{fp}} = 494$ N.

(b) The fact that the result is positive means $\vec{F}_{\text{fp}}$ points up.

(c) Newton's third law indicates $\vec{F}_{\text{fp}} = -\vec{F}_{\text{pf}}$, which leads to the conclusion that $|\vec{F}_{\text{pf}}| = 494\text{ N}$.

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

28. The stopping force $\vec{F}$ and the path of the toothpick are horizontal. Our $+x$ axis is in the direction of the toothpick's motion, so that the toothpick's acceleration ("deceleration") is negative-valued and the stopping force is in the $-x$ direction: $\vec{F} = -F\,\hat{\mathrm{i}}$. Using Eq. 2-16 with $v_0 = 220$ m/s and $v = 0$, the acceleration is found to be

$$v^2 = v_0^2 + 2a\Delta x \;\;\Rightarrow\;\; a = -\frac{v_0^2}{2\Delta x} = -\frac{(220\ \text{m/s})^2}{2(0.015\ \text{m})} = -1.61\times10^6\ \text{m/s}^2.$$

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

$$F = m\,|a| = (1.3\times10^{-4}\ \text{kg})(1.61\times10^6\ \text{m/s}^2) = 2.1\times10^2\ \text{N}.$$

29. 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

$$y = \frac{1}{2}\frac{F}{m}\left(\frac{x}{v_0}\right)^2 = \frac{1}{2}\left(\frac{4.5\times10^{-16}\ \text{N}}{9.11\times10^{-31}\ \text{kg}}\right)\left(\frac{30\times10^{-3}\ \text{m}}{1.2\times10^{7}\ \text{m/s}}\right)^2 = 1.5\times10^{-3}\ \text{m} .$$

30. 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: $\vec{F} = -F\,\hat{\mathrm{i}}$.

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

$$v^2 = v_0^2 + 2a\Delta x \quad \Rightarrow \quad a = -\frac{v_0^2}{2\Delta x} = -\frac{(11.1\text{ m/s})^2}{2(15\text{ m})}$$

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

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

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 (b).

31. The acceleration vector as a function of time is

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}\left(8.00t\,\hat{\mathrm{i}} + 3.00t^2\,\hat{\mathrm{j}}\right)\text{ m/s} = (8.00\,\hat{\mathrm{i}} + 6.00t\,\hat{\mathrm{j}})\text{ m/s}^2.$$

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

$$F = ma = m\,|\,\vec{a}\,| = (3.00)\sqrt{(8.00)^2 + (6.00t)^2} = (3.00)\sqrt{64.0 + 36.0\,t^2}\text{ N}.$$

Thus, $F = 35.0\text{ N}$ corresponds to $t = 1.415\text{ s},$ and the acceleration vector at this instant is

$$\vec{a} = [8.00\,\hat{\mathrm{i}} + 6.00(1.415)\,\hat{\mathrm{j}}]\text{ m/s}^2 = (8.00\text{ m/s}^2)\,\hat{\mathrm{i}} + (8.49\text{ m/s}^2)\hat{\mathrm{j}}.$$

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

$$\theta_a = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{8.49\text{ m/s}^2}{8.00\text{ m/s}^2}\right) = 46.7°.$$

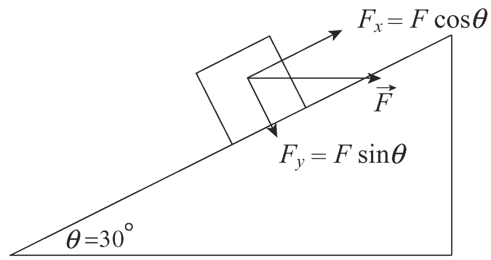
(b) The velocity vector at $t = 1.415\text{ s}$ is

$$\vec{v} = \left[8.00(1.415)\,\hat{\mathrm{i}} + 3.00(1.415)^2\,\hat{\mathrm{j}}\right]\text{m/s} = (11.3\text{ m/s})\,\hat{\mathrm{i}} + (6.01\text{ m/s})\hat{\mathrm{j}}.$$

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

$$\theta_v = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{6.01\text{ m/s}}{11.3\text{ m/s}}\right) = 28.0°.$$

32. We resolve this horizontal force into appropriate components.



(a) 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

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

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

33. (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 = 15 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 $x_g = x_s$, or

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

This occurs at time

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

By then, the girl has gone the distance

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

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

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

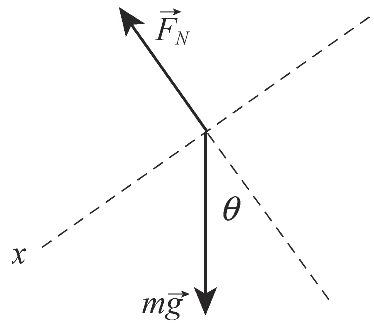
Thus, $\vec{F}_3 = (1.70\text{ N})\,\hat{\text{i}} + (3.06\text{ N})\hat{\text{j}}$.

(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

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

35. The free-body diagram is shown next. $\vec{F}_N$ 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 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

$$x = -\frac{1}{2}\frac{v_0^2}{a} = -\frac{1}{2}\left(\frac{(-3.50 \text{ m/s})^2}{\left(9.8 \text{ m/s}^2\right) \sin 32.0°}\right) = -1.18 \text{ m},$$

or $|x| = 1.18$ m.

(b) The time is

$$t = \frac{v_0}{a} = -\frac{v_0}{g \sin \theta} = -\frac{-3.50 \text{m/s}}{\left(9.8 \text{m/s}^2\right) \sin 32.0°} = 0.674 \text{s}.$$

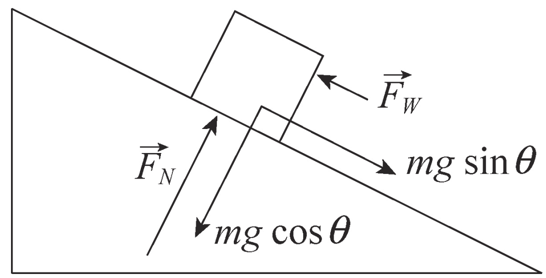
(c) That the return-speed is identical to the initial speed is to be expected since there are no dissipative forces in this problem. In order to prove this, one approach is to set $x = 0$ and solve $x = v_0 t + \frac{1}{2}at^2$ for the total time (up and back down) *t*. The result is

$$t = -\frac{2v_0}{a} = -\frac{2v_0}{g \sin \theta} = -\frac{2(-3.50 \text{ m/s})}{\left(9.8 \text{ m/s}^2\right) \sin 32.0°} = 1.35 \text{ s}.$$

The velocity when it returns is therefore

$$v = v_0 + at = v_0 + gt \sin \theta = -3.50 \text{ m/s} + (9.8 \text{ m/s}^2)(1.35 \text{ s}) \sin 32° = 3.50 \text{ m/s}.$$

36. 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

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

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

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

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

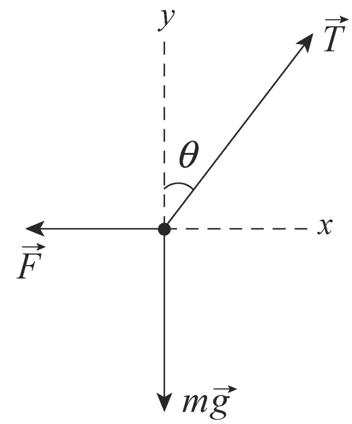
now leads to $F_w = 28$ N (uphill).

(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 $|a| = 2.0$ 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*.

37. 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 sphere is motionless the net force on it is zero, and the x and the y components of the equations are:



$$T \sin \theta - F = 0$$
$$T \cos \theta - mg = 0,$$

where $\theta = 37°$. We answer the questions in the reverse order. Solving $T \cos \theta - mg = 0$ for the tension, we obtain

$$T = mg / \cos \theta = (3.0 \times 10^{-4}\ \text{kg})\ (9.8\ \text{m/s}^2) / \cos 37° = 3.7 \times 10^{-3}\ \text{N}.$$

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

$$F = T \sin \theta = (3.7 \times 10^{-3}\ \text{N}) \sin 37° = 2.2 \times 10^{-3}\ \text{N}.$$

38. The acceleration of an object (neither pushed nor pulled by any force other than gravity) on a smooth inclined plane of angle θ is $a = -\,g\sin\theta$. The slope of the graph shown with the problem statement indicates a = –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 = 5.00 kg. Thus, the normal (perpendicular) force exerted at the box/ramp interface is 47.4 N.

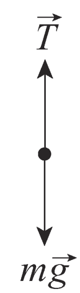
39. The free-body diagram is shown below. Let $\vec{T}$ be the tension of the cable and $m\vec{g}$ be the force of gravity. If the upward direction is positive, then Newton's second law is $T - mg = ma$, where a is the acceleration.

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, $v_0 = -12$ m/s is the initial velocity, and $y = -42$ m is the coordinate at the stopping point). Consequently, $v^2 = v_0^2 + 2ay$ leads to

$$a = -\frac{v_0^2}{2y} = -\frac{(-12\ \mathrm{m/s})^2}{2(-42\ \mathrm{m})} = 1.71\ \mathrm{m/s^2}.$$

We now return to calculate the tension:

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



40. (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 $\theta = 8.0°$, 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) yields

$$T - mg \sin \theta = ma \quad \Rightarrow \quad T - (50\text{ kg})(9.8\text{ m/s}^2)\sin 8.0° = (50\text{ kg})(0.10\text{ m/s}^2)$$

which leads to T = 73 N.

41. (a) The mass of the elevator is $m = (27800/9.80) = 2837$ kg and (with $+y$ upward) the acceleration is $a = +1.22\ \text{m/s}^2$. Newton's second law leads to

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

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 $a = -1.22\ \text{m/s}^2$, so that the tension is

$$T = m\,(g + a) = 2.43 \times 10^4\ \text{N}\,.$$

42. (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

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

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, lead us right back to $T = 89$ N. Since the direction of the velocity did not enter our computation, this is to be expected.

43. The mass of the bundle is m = (449 N)/(9.80 m/s^2) = 45.8 kg and we choose $+y$ upward.

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

$$T - mg = ma \;\Rightarrow\; a = \frac{387\text{ N} - 449\text{ N}}{45.8\text{ kg}}$$

which yields a = –1.4 m/s^2 (or $|a|$ = 1.4 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 Δy = –6.1 m). We assume v_0 = 0.

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

For downward accelerations greater than 1.4 m/s^2, the speeds at impact will be larger than 4.1 m/s.

44. With a_{ce} meaning "the acceleration of the coin relative to the elevator" and a_{eg} meaning "the acceleration of the elevator relative to the ground", we have

$$a_{ce} + a_{eg} = a_{cg} \quad \Rightarrow \quad -8.00 \text{ m/s}^2 + a_{eg} = -9.80 \text{ m/s}^2$$

which leads to $a_{eg} = -1.80$ m/s^2. We have chosen upward as the positive y direction. Then Newton's second law (in the "ground" reference frame) yields $T - m\,g = m\,a_{eg}$, or

$$T = m\,g + m\,a_{eg} = m(g + a_{eg}) = (2000 \text{ kg})(8.00 \text{ m/s}^2) = 16.0 \text{ kN}.$$

45. (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 $\vec{F}_{2on1}$ of link 2, upward. Take the positive direction to be upward. Then Newton's second law for this link is $F_{2on1} - mg = ma$. Thus,

$$F_{2on1} = m(a + g) = (0.100 \text{ kg})\,(2.50 \text{ m/s}^2 + 9.80 \text{ m/s}^2) = 1.23 \text{ N}.$$

(b) The forces on the second link are the force of gravity $m\vec{g}$, downward, the force $\vec{F}_{1on2}$ of link 1, downward, and the force $\vec{F}_{3on2}$ of link 3, upward. According to Newton's third law $\vec{F}_{1on2}$ has the same magnitude as $\vec{F}_{2on1}$. Newton's second law for the second link is $F_{3on2} - F_{1on2} - mg = ma$, so

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

(c) Newton's second for link 3 is $F_{4on3} - F_{2on3} - mg = ma$, so

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

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

(d) Newton's second law for link 4 is $F_{5on4} - F_{3on4} - mg = ma$, so

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

where Newton's third law implies $F_{3on4} = F_{4on3}$.

(e) Newton's second law for the top link is $F - F_{4on5} - mg = ma$, so

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

where $F_{4on5} = F_{5on4}$ by Newton's third law.

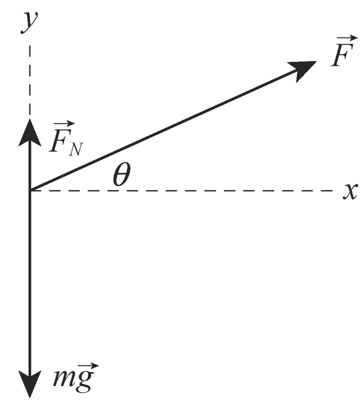
(f) Each link has the same mass and the same acceleration, so the same net force acts on each of them:

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

46. Applying Newton's second law to cab B (of mass m) we have $a = \frac{T}{m} - g = 4.89 \text{ m/s}^2$. Next, we apply it to the box (of mass m_b) to find the normal force:

$$F_N = m_b(g + a) = 176 \text{ N}.$$

47. The free-body diagram (not to scale) for the block is shown below. $\vec{F}_N$ 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):

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

48. The direction of motion (the direction of the barge's acceleration) is $+\hat{\mathrm{i}}$, and $+\vec{\mathrm{j}}$ 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

$$(7900\,\mathrm{N})\cos 18° + F_x = ma$$
$$(7900\,\mathrm{N})\sin 18° + F_y = 0$$

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

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

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

$$\tan^{-1}\left(\frac{F_y}{F_x}\right) = +21° \text{ or } 201°.$$

The signs of the components indicate the latter is correct, so $\vec{F}_{\text{water}}$ is at 201° measured counterclockwise from the line of motion (+x axis).

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

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

The horizontal and vertical components of the speed are

$$v_x = v_0 \cos\theta = (26.52\ \text{m/s})\cos 53^\circ = 15.96\ \text{m/s}$$
$$v_y = v_0 \sin\theta = (26.52\ \text{m/s})\sin 53^\circ = 21.18\ \text{m/s}.$$

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

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

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

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

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.

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

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

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

$$\begin{aligned} T_4 - T_2 &= \left(m_3 + m_4\right)a \\ 111\,\text{N} &= \left(15\ \text{kg} + 20\,\text{kg}\right)a \quad \Rightarrow \quad a = 3.2\ \text{m/s}^2. \end{aligned}$$

Substituting the value, we obtain $m_2 = 23$ kg.

51. 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. 5-49.

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

$$T_3 = m_{\text{sys}}a \quad \Rightarrow \quad 65.0\,\text{N} = (67.0\,\text{kg})a$$

which yields $a = 0.970$ 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.

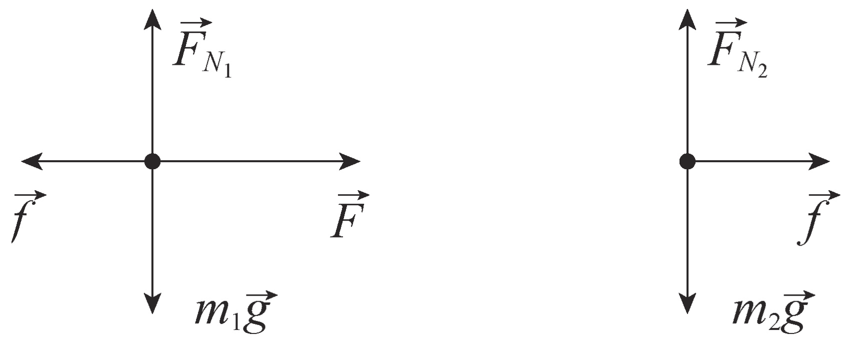
$$T_2 = (m_1 + m_2)a = (12.0\text{ kg} + 24.0\text{ kg})\left(0.970\text{ m/s}^2\right) = 34.9\text{ N}.$$

52. 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 twice as big as the (direct) force causing *A* to have that acceleration. Therefore, *B* has the twice the mass of *A*. Since their total is given as 12.0 kg then *B* has a mass of m_B = 8.00 kg and *A* has mass m_A = 4.00 kg. Considering the first figure, (20.0 N)/(8.00 kg) = 2.50 m/s^2. Of course, the same result comes from considering the second figure ((10.0 N)/(4.00 kg) = 2.50 m/s^2).

(b) F_a = (12.0 kg)(2.50 m/s^2) = 30.0 N

53. 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).

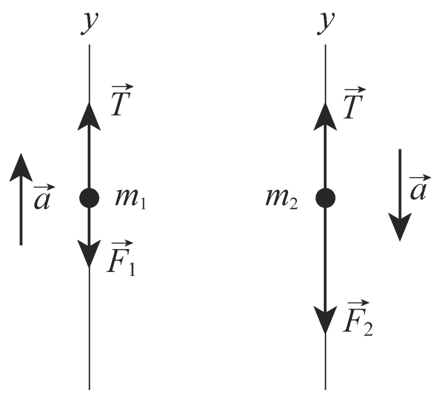
54. (a) The net force on the *system* (of total mass M = 80.0 kg) is the force of gravity acting on the total overhanging mass (m_{BC} = 50.0 kg). The magnitude of the acceleration is therefore $a = (m_{BC}\, g)/M = 6.125$ m/s^2. Next we apply Newton's second law to block C itself (choosing *down* as the +y direction) and obtain

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

This leads to T_{BC} = 36.8 N.

(b) We use Eq. 2-15 (choosing *rightward* as the +x direction): $\Delta x = 0 + \frac{1}{2}at^2 = 0.191$ m.

55. 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 Newton's 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

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

(b) Similarly, the tension in the cord is

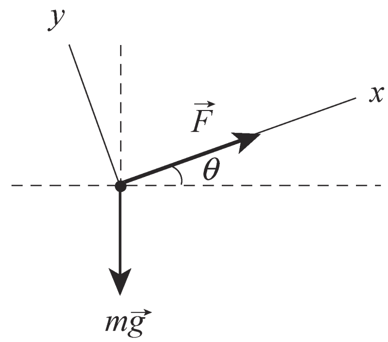
$$T = \frac{2(1.30 \text{ kg})(2.80 \text{ kg})}{1.30 \text{ kg} + 2.80 \text{ kg}} (9.80 \text{ m/s}^2) = 17.4 \text{ N}.$$

56. 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

$$\frac{12.76\text{ m/s} - 12.54\text{ m/s}}{12.76\text{ m/s}} = 0.0169 = 16.9\%.$$

57. 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

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

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 $F = m_p g$. 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, 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:

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

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

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

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

58. 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 different between the weight of the man and that of the sandbag. The system mass is m_{sys} = 85 kg + 65 kg = 150 kg. Thus, Eq. 5-1 leads to

$$(85\text{ kg})(9.8\text{ m/s}^2) - (65\text{ kg})(9.8\text{ m/s}^2) = m_{sys}\, a$$

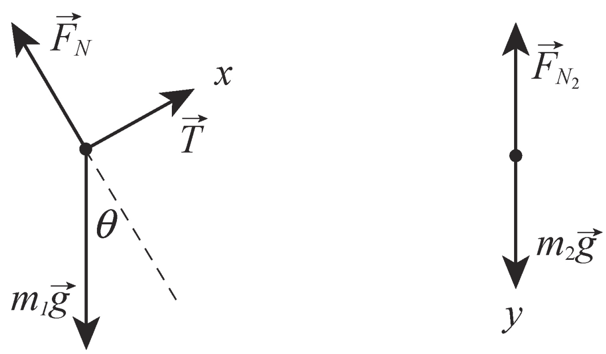
which yields a = 1.3 m/s^2. Since the system starts from rest, Eq. 2-16 determines the speed (after traveling Δy = 10 m) as follows:

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

59. 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 $\vec{F}_N$ 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 Newton's second law to the x and y axes for block 1 and to the y axis of block 2, we obtain

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

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).



(a) We add the first and third equations above:

$$m_2 g - m_1 g \sin\theta = m_1 a + m_2 a.$$

Consequently, we find

$$a = \frac{(m_2 - m_1 \sin\theta)g}{m_1 + m_2} = \frac{[2.30\text{ kg} - (3.70\text{ kg})\sin 30.0°](9.80\text{ m/s}^2)}{3.70\text{ kg} + 2.30\text{ kg}} = 0.735\text{ m/s}^2.$$

(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

$$T = m_1 a + m_1 g \sin\theta = (3.70\text{ kg})(0.735\text{ m/s}^2) + (3.70\text{ kg})(9.80\text{ m/s}^2)\sin 30.0° = 20.8\text{N}.$$

60. 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 $a = +1.30$ 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 $a = +1.30$ m/s^2, the equation in (c) yields $T = 1.05 \times 10^3$ 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.

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

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

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

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

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

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

$$\frac{da_x}{dt} = \frac{d}{dt}\left(\frac{F\cos\theta}{m}\right) = -\frac{F\sin\theta}{m}\frac{d\theta}{dt} = -\frac{(20.0\ \mathrm{N})\sin 25.0°}{5.00\ \mathrm{kg}}\left(3.49\times10^{-4}\,\mathrm{rad/s}\right)$$
$$= -5.90\times10^{-4}\ \mathrm{m/s^3}.$$

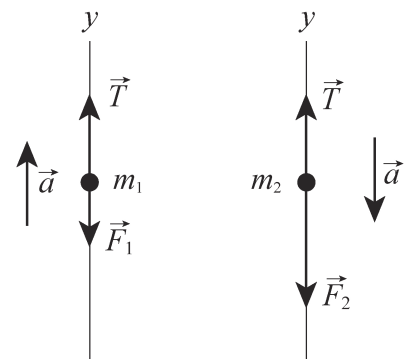
(b) If the rate of change of the angle is

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

then the rate of change of acceleration would be

$$\frac{da_x}{dt} = \frac{d}{dt}\left(\frac{F\cos\theta}{m}\right) = -\frac{F\sin\theta}{m}\frac{d\theta}{dt} = -\frac{(20.0\ \mathrm{N})\sin 25.0°}{5.00\ \mathrm{kg}}\left(-3.49\times10^{-4}\,\mathrm{rad/s}\right)$$
$$= +5.90\times10^{-4}\ \mathrm{m/s^3}.$$

63. 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 Newton's 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, $m_1 = m_{10} + (dm_1/dt)t = 1.30\text{ kg} + (-0.200\text{ kg/s})(3.00\text{ s}) = 0.700$ 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.

64. 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 $(x, y) = (15.90\text{ m}, 0)$, we find the launch speed to be $v' = 11.85$ m/s. During this phase, the acceleration is

$$a = \frac{v'^2 - v_0^2}{2L} = \frac{(11.85\text{ m/s})^2 - (2.50\text{ m/s})^2}{2(1.65\text{ m})} = 40.63\text{ m/s}^2.$$

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

$$F = m(a + g\sin\theta) = (7.260\text{ kg})\left[40.63\text{ m/s}^2 + (9.80\text{ m/s}^2)\sin 34.10°\right] = 334.8\text{ N}.$$

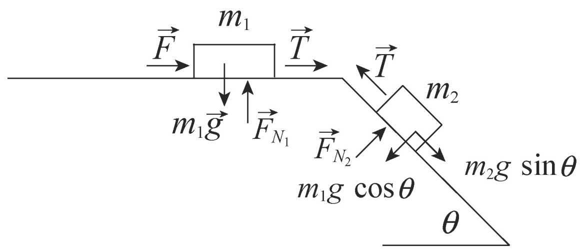
65. First we analyze the entire *system* with "clockwise" motion considered positive (that is, downward is positive for block C, rightward is positive for block B, and upward is positive for block A): $m_C g - m_A g = Ma$ (where M = mass of the *system* = 24.0 kg). This yields an acceleration of

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

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

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

66. The $+x$ direction for m_2=1.0 kg is "downhill" and the $+x$ direction for m_1=3.0 kg is rightward; thus, they accelerate with the same sign.



(a) We apply Newton's 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:

$$a = \frac{m_2g\sin\theta + F}{m_1 + m_2}$$

With F = 2.3 N and $\theta = 30°$, we have a = 1.8 m/s^2. We plug back and find 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 m/s^2. This implies (along with T = 0 in the second equation in part (a)) that

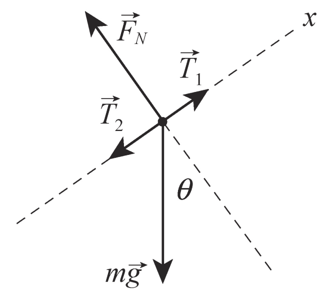
$$F = (3.0\text{ kg})(4.9\text{ m/s}^2) = 14.7\text{ N} \approx 15\text{ N}$$

in the critical case.

67. (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 "area" in the graph (15 units) and divide by the mass (3) to obtain $v - v_o = 15/3 = 5$. 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.

68. The free-body diagram is shown on the right. 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:

$$T_1 - T_2 = m\left(g\sin\theta + a\right) = \left(2800\text{ kg}\right)\left[(9.8\text{ m/s}^2)\sin 35° + 0.81\text{ m/s}^2\right]$$
$$= 1.8\times10^4\ \text{N}.$$

69. (a) We quote our answers to many figures – probably more than are truly "significant." Here (7682 L)("1.77 kg/L") = 13597 kg. The quotation marks around the 1.77 are due to the fact that this was believed (by the flight crew) to be a legitimate conversion factor (it is not).

(b) The amount they felt should be added was 22300 kg – 13597 kg = 87083 kg, which they believed to be equivalent to (87083 kg)/("1.77 kg/L") = 4917 L.

(c) Rounding to 4 figures as instructed, the conversion factor is 1.77 lb/L $\rightarrow$ 0.8034 kg/L, so the amount on board was (7682 L)(0.8034 kg/L) = 6172 kg.

(d) The implication is that what as needed was 22300 kg – 6172 kg = 16128 kg, so the request should have been for (16128 kg)/(0.8034 kg/L) = 20075 L.

(e) The percentage of the required fuel was

$$\frac{7682\text{ L (on board)} + 4917\text{ L (added)}}{(22300\text{ kg required})/(0.8034\text{ kg/L})} = 45\%.$$

70. We are only concerned with horizontal forces in this problem (gravity plays no direct role). Without loss of generality, we take one of the forces along the $+x$ direction and the other at 80° (measured counterclockwise from the x axis). This calculation is efficiently implemented on a vector capable calculator in polar mode, as follows (using magnitude-angle notation, with angles understood to be in degrees):

$$\vec{F}_{\text{net}} = (20 \angle 0) + (35 \angle 80) = (43 \angle 53) \Rightarrow |\vec{F}_{\text{net}}| = 43 \text{ N} .$$

Therefore, the mass is $m = (43 \text{ N})/(20 \text{ m/s}^2) = 2.2$ kg.

71. 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

$$-50\ \text{N} = F_{2x} + F_{3x} = -(30\text{N})\cos\theta - (30\text{N})\cos\theta$$

which leads to

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

72. (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:

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

73. 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. We also note that the x component of the rope's tension (acting on the crate) is

$$F_x = F\cos\theta = (450\text{ N})\cos 38° = 355\text{ N},$$

and the resistive force (pointing in the $-x$ direction) has magnitude $f = 125$ N.

(a) Newton's second law leads to

$$F_x - f = ma \Rightarrow a = \frac{355\text{ N} - 125\text{ N}}{310\text{ kg}} = 0.74\,\text{m/s}^2.$$

(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

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

74. 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

$$\vec{F}_3 = -\vec{F}_1 - \vec{F}_2 = -\left(2\hat{\text{i}} + 3\hat{\text{j}} - 2\hat{\text{k}}\right)\text{N} - \left(-5\hat{\text{i}} + 8\hat{\text{j}} - 2\hat{\text{k}}\right)\text{N} = \left(3\hat{\text{i}} - 11\hat{\text{j}} + 4\hat{\text{k}}\right)\text{N}.$$

The specific value of the velocity is not used in the computation.

75. (a) Since the performer's weight is (52 kg)(9.8 m/s^2) = 510 N, the rope breaks.

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

$$T - mg = ma \;\Rightarrow\; a = \frac{T}{m} - g$$

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

76. (a) For the 0.50 meter drop in "free-fall", Eq. 2-16 yields a speed of 3.13 m/s. Using this as the "initial speed" for the final motion (over 0.02 meter) during which his motion slows at rate "a", we find the magnitude of his average acceleration from when his feet first touch the patio until the moment his body stops moving is $a = 245\text{ m/s}^2$.

(b) We apply Newton's second law: $F_{\text{stop}} - mg = ma \;\Rightarrow\; F_{\text{stop}} = 20.4\text{ kN}$.

77. We begin by examining a slightly different problem: similar to this figure but without the string. The motivation is that if (without the string) block A is found to accelerate faster (or exactly as fast) as block B then (returning to the original problem) the tension in the string is trivially zero. In the absence of the string,

$$a_A = F_A / m_A = 3.0 \text{ m/s}^2$$

$$a_B = F_B / m_B = 4.0 \text{ m/s}^2$$

so the trivial case does not occur. We now (with the string) consider the net force on the *system*: $Ma = F_A + F_B = 36$ N. Since $M = 10$ kg (the total mass of the system) we obtain $a = 3.6$ m/s^2. The two forces on block A are F_A and T (in the same direction), so we have

$$m_A a = F_A + T \quad \Rightarrow \quad T = 2.4 \text{ N.}$$

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

$$\vec{F}_{\text{net}} = \left(3.0 + 14\cos 30° - 11\right)\hat{\text{i}} + \left(14\sin 30° + 5.0 - 17\right)\hat{\text{j}}$$

which yields $\vec{F}_{\text{net}} = (4.1\text{ N})\,\hat{\text{i}} - (5.0\text{ N})\hat{\text{j}}$.

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

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m} = (1.0\,\text{m/s}^2)\hat{\text{i}} - (1.3\,\text{m/s}^2)\hat{\text{j}}\,.$$

(b) The magnitude of $\vec{a}$ is $a = \sqrt{(1.0\text{ m/s}^2)^2 + \left(-1.3\text{ m/s}^2\right)^2} = 1.6\ \text{m/s}^2$.

(c) Its angle is $\tan^{-1}$ [(–1.3 m/s^2)/(1.0 m/s^2)] = –50° (that is, 50° measured clockwise from the rightward axis).

79. The "certain force" denoted F is assumed to be the net force on the object when it gives m_1 an acceleration $a_1 = 12\ \text{m/s}^2$ and when it gives m_2 an acceleration $a_2 = 3.3\ \text{m/s}^2$. 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 $a = 4.6\ \text{m/s}^2$.

(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 $a = 2.6\ \text{m/s}^2$.

80. 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 N), then the acceleration is zero, so $mg - F_1 = 0$. If the thrust is F_2 (= 2200 N), then the acceleration is a_2 (= 0.39 m/s^2), so $mg - F_2 = ma_2$.

(a) The first equation gives the weight of the landing craft: $mg = F_1 = 3260$ 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:

$$g = (3260 \text{ N})/(2.7 \times 10^3 \text{ kg}) = 1.2 \text{ m/s}^2.$$

81. From the reading when the elevator was at rest, we know the mass of the object is $m = (65\ \text{N})/(9.8\ \text{m/s}^2) = 6.6$ 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 ($a = -2.4\ \text{m/s}^2$). Newton's second law gives

$$T - mg = ma \;\Rightarrow\; T = (6.6\ \text{kg})(9.8\ \text{m/s}^2 - 2.4\ \text{m/s}^2) = 49\ \text{N}.$$

82. We take $+x$ uphill for the $m_2 = 1.0$ kg box and $+x$ rightward for the $m_1 = 3.0$ kg box (so the accelerations of the two boxes have the same magnitude and the same sign). The uphill force on m_2 is F and the downhill forces on it are T and $m_2 g \sin\theta$, where $\theta = 37°$. The only horizontal force on m_1 is the rightward-pointed tension. Applying Newton's second law to each box, we find

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

which can be added to obtain $F - m_2 g \sin\theta = (m_1 + m_2)a$. This yields the acceleration

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

Thus, the tension is $T = m_1 a = (3.0 \text{ kg})(1.53 \text{ m/s}^2) = 4.6$ N.

83. We apply Eq. 5-12.

(a) The mass is $m = W/g = (22\ \text{N})/(9.8\ \text{m/s}^2) = 2.2$ kg. At a place where $g = 4.9\ \text{m/s}^2$, the mass is still 2.2 kg but the gravitational force is $F_g = mg = (2.2\ \text{kg})\ (4.0\ \text{m/s}^2) = 11$ 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.

84. 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

$$W_e = mg_e = (75 \text{ kg})\,(9.8 \text{ m/s}^2) = 7.4 \times 10^2 \text{ N}.$$

(b) The weight of the space ranger on Mars is

$$W_m = mg_m = (75 \text{ kg})\,(3.7 \text{ m/s}^2) = 2.8 \times 10^2 \text{ N}.$$

(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, m=75 kg, at all the locations.

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

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

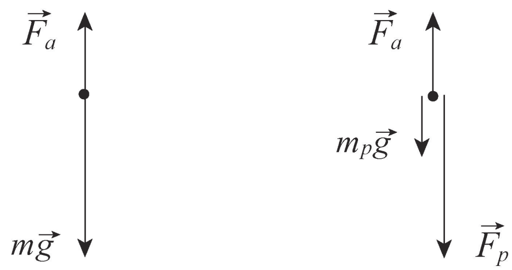
for the force exerted by each bolt on the engine.

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

$$F = \frac{1}{3}m(g + a) = \frac{1}{3}(1400 \text{ kg})\left(9.8 \text{ m/s}^2 + 2.6 \text{ m/s}^2\right) = 5.8 \times 10^3 \text{ N}.$$

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

(a) The first diagram (shown below left) is the free-body diagram for the person and parachute, considered as a single object with a mass of 80 kg + 5.0 kg = 85 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 right) 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

$$F_p = m_p(a - g) + F_a = (5.0\ \text{kg})(2.5\ \text{m/s}^2 - 9.8\ \text{m/s}^2) + 620\ \text{N} = 580\ \text{N}.$$

87. (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). Thus, m = 4.0 kg.

The acceleration of the system and the tension in the cord can be readily obtained by solving

$$mg - T = ma$$
$$T = Ma.$$

(b) The acceleration is given by

$$a = \left(\frac{m}{m+M}\right) g = 6.5 \text{ m/s}^2.$$

(c) The tension is

$$T = Ma = \left(\frac{Mm}{m+M}\right) g = 13 \text{ N}.$$

88. We assume the direction of motion is $+x$ and assume the refrigerator starts from rest (so that the speed being discussed is the velocity $\vec{v}$ 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

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

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

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

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 $\sqrt{\cos\theta}$.

89. 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

$$F - mg_{\text{moon}} = ma \quad \Rightarrow \quad F = (75\text{ kg})\left(1.6\ \text{m/s}^2 + 1.0\ \text{m/s}^2\right) = 195\ \text{N}.$$

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

$$T - Mg = Ma \;\Rightarrow\; a = \frac{2.6\times10^5\ \text{N}}{1.3\times10^4\ \text{kg}} - 9.8\ \text{m/s}^2 = 10\,\text{m/s}^2.$$

91. (a) The bottom cord is only supporting $m_2 = 4.5$ kg against gravity, so its tension is

$$T_2 = m_2 g = (4.5 \text{ kg})(9.8 \text{ m/s}^2) = 44 \text{ N}.$$

(b) The top cord is supporting a total mass of $m_1 + m_2 = (3.5 \text{ kg} + 4.5 \text{ kg}) = 8.0$ kg against gravity, so the tension there is

$$T_1 = (m_1 + m_2)g = (8.0 \text{ kg})(9.8 \text{ m/s}^2) = 78 \text{ N}.$$

(c) In the second picture, the lowest cord supports a mass of $m_5 = 5.5$ kg against gravity and consequently has a tension of $T_5 = (5.5 \text{ kg})(9.8 \text{ m/s}^2) = 54$ N.

(d) The top cord, we are told, has tension $T_3 = 199$ N which supports a total of (199 N)/(9.80 m/s^2) = 20.3 kg, 10.3 kg of which is already accounted for in the figure. Thus, the unknown mass in the middle must be $m_4 = 20.3 \text{ kg} - 10.3 \text{ kg} = 10.0$ kg, and the tension in the cord above it must be enough to support

$$m_4 + m_5 = (10.0 \text{ kg} + 5.50 \text{ kg}) = 15.5 \text{ kg},$$

so $T_4 = (15.5 \text{ kg})(9.80 \text{ m/s}^2) = 152$ N. Another way to analyze this is to examine the forces on m_3; one of the downward forces on it is T_4.

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

$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 = \left(3.0\text{ N} + \left(-2.0\text{ N}\right)\right)\hat{\text{i}} + \left(4.0\text{ N} + \left(-6.0\text{ N}\right)\right)\hat{\text{j}}$$

which yields $\vec{F}_{\text{net}} = (1.0\text{ N})\hat{\text{i}} - (2.0\text{ N})\hat{\text{j}}$.

(b) The magnitude of $\vec{F}_{\text{net}}$ is $F_{\text{net}} = \sqrt{(1.0\text{ N})^2 + (-2.0\text{ N})^2} = 2.2\text{ N}$.

(c) The angle of $\vec{F}_{\text{net}}$ is

$$\theta = \tan^{-1}\left(\frac{-2.0\text{ N}}{1.0\text{ N}}\right) = -63°.$$

(d) The magnitude of $\vec{a}$ is

$$a = F_{\text{net}}/m = (2.2\text{ N})/(1.0\text{ kg}) = 2.2\text{ m/s}^2.$$

(e) Since $\vec{F}_{\text{net}}$ is equal to $\vec{a}$ multiplied by mass m, which is a positive scalar that cannot affect the direction of the vector it multiplies, $\vec{a}$ has the same angle as the net force, i.e, $\theta = -63°$. In magnitude-angle notation, we may write $\vec{a} = \left(2.2\text{ m/s}^2 \angle -63°\right)$.

93. 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:

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

The magnitude of the force is consequently

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

94. 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 $a = +1.4 \text{ m/s}^2$ for both the helicopter and the truck.

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

$$F_{\text{lift}} - T - Mg = Ma$$
$$T - mg = ma$$

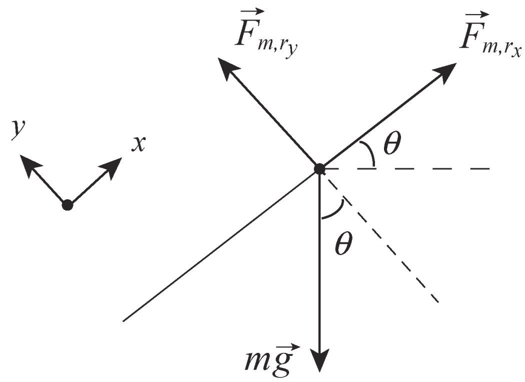
which we add together to obtain

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

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.

95. The free-body diagrams is shown on the right. Note that $F_{\text{m, r}_y}$ 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.



(a) Since the net force equals ma, then the magnitude of the net force on the rider is (60.0 kg) (3.0 m/s^2) = 1.8×10^2 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 θ = 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

$$\sqrt{F^2_{m,r_x} + F^2_{m,r_y}} = 644 \text{ N.}$$

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, to two significant figures.

96. We write the length unit light-month, the distance traveled by light in one month, as c·month in this solution.

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

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

(b) The acceleration in terms of g is

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

(c) The force needed is

$$F = ma = (1.20 \times 10^6 \text{ kg})(1.2 \times 10^2 \text{ m/s}^2) = 1.4 \times 10^8 \text{ N}.$$

(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

$$t = \frac{d}{v} = \frac{5.0 \text{ c} \cdot \text{months}}{0.1c} = 50 \text{ months} \approx 4.2 \text{ years}.$$

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

(a) We write the velocity of the armadillo as $\vec{v} = v_x\,\hat{\text{i}} + v_y\,\hat{\text{j}}$. 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 $v_{0y} = 0$)

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

Thus, $\vec{v} = (5.0\,\text{m/s})\,\hat{\text{i}} + (4.3\,\text{m/s})\,\hat{\text{j}}$.

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

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

The position vector at t = 3.0 s is therefore

$$\vec{r} = (15\text{ m})\hat{\text{i}} + (6.4\text{ m})\hat{\text{j}}.$$

98. (a) From Newton's second law, the magnitude of the maximum force on the passenger from the floor is given by

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

we obtain F_N = 590 N for m = 50 kg.

(b) The direction is upward.

(c) Again, we use Newton's second law, the magnitude of the minimum force on the passenger from the floor is given by

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

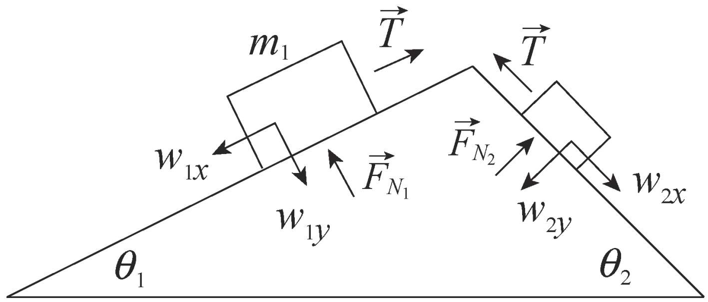
Now, we obtain F_N= 340 N.

(d) The direction is upward.

(e) 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.

(f) The direction is downward.

99. The $+x$ axis is "uphill" for $m_1 = 3.0$ kg and "downhill" for $m_2 = 2.0$ kg (so they both accelerate with the same sign). The x components of the two masses along the x axis are given by $w_{1x} = m_1 g \sin\theta_1$ and $w_{2x} = m_2 g \sin\theta_2$, respectively.



Applying Newton's second law, we obtain

$$T - m_1 g \sin\theta_1 = m_1 a$$
$$m_2 g \sin\theta_2 - T = m_2 a$$

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

$$a = \left(\frac{m_2 \sin\theta_2 - m_1 \sin\theta_1}{m_2 + m_1}\right) g$$

With $\theta_1 = 30°$ and $\theta_2 = 60°$, we have $a = 0.45$ m/s^2. This value is plugged back into either of the two equations to yield the tension $T = 16$ N.

100. (a) In unit vector notation,

$$m\vec{a} = (-\,3.76\text{ N})\,\hat{\text{i}} + (1.37\text{ N})\,\hat{\text{j}}.$$

Thus, Newton's second law leads to

$$\vec{F}_2 = m\vec{a} - \vec{F}_1 = (-\,6.26\text{ N})\,\hat{\text{i}} - (3.23\text{ N})\,\hat{\text{j}}.$$

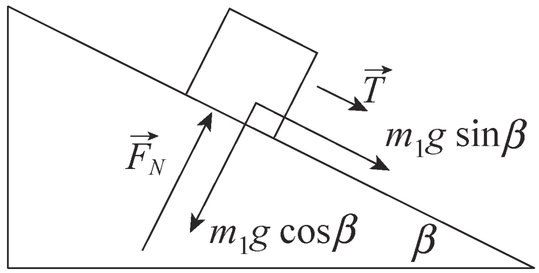
(b) The magnitude of $\vec{F}_2$ is $F_2 = \sqrt{(-6.26\text{ N})^2 + (-3.23\text{ N})^2} = 7.04\text{ N}.$

(c) Since $\vec{F}_2$ is in the third quadrant, the angle is

$$\theta = \tan^{-1}\left(\frac{-3.23\text{ N}}{-6.26\text{ N}}\right) = 207°.$$

counterclockwise from positive direction of x axis (or 153° *clockwise* from $+x$).

101. We first analyze the forces on m_1=1.0 kg.



The +x direction is "downhill" (parallel to $\vec{T}$).

With the acceleration (5.5 m/s^2) in the positive x direction for m_1, then Newton's second law, applied to the x axis, becomes

$$T + m_1 g \sin\beta = m_1\left(5.5\,\text{m/s}^2\right)$$

But for m_2=2.0 kg, using the more familiar vertical y axis (with *up* as the positive direction), we have the acceleration in the negative direction:

$$F + T - m_2 g = m_2\left(-5.5\,\text{m/s}^2\right)$$

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

(a) From the equation for m_2, with F = 6.0 N, we find the tension T = 2.6 N.

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

102. (a) The word “hovering” is taken to imply that the upward (thrust) force is equal in magnitude to the downward (gravitational) force: $mg = 4.9 \times 10^5$ N.

(b) Now the thrust must exceed the answer of part (a) by $ma = 10 \times 10^5$ N, so the thrust must be 1.5×10^6 N.

103. (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 $a = 4.1 \text{ m/s}^2$.

(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.

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

$$a = \frac{v^2}{2\Delta x} = \frac{(6.0\times10^6 \text{ m/s})^2}{2(0.015 \text{ m})} = 1.2\times10^{15} \text{ m/s}^2.$$

The force responsible for producing this acceleration is

$$F = ma = (9.11\times 10^{-31} \text{ kg})\,(1.2\times10^{15} \text{ m/s}^2) = 1.1\times10^{-15} \text{ N}.$$

(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.