4.1

As the ball reaches the top of its path it has no vertical velocity: $v_y = 0$. Also, since the ball has no horizontal velocity relative to the bus, its horizontal velocity relative to the stationary person outside the bus is equal to that of the bus. Hence $\vec{v} = (10\,\mathrm{m/s})$-horizontal.

4.3

The vertical separation between the grapes and the open mouth of Marc Antony is $s_y = 1.0000\,\mathrm{m}$. Since the grapes are released with no initial vertical velocity, their time-of-flight t satisfies $s_y = \frac{1}{2}gt^2$, or $t = \sqrt{2s_y/g}$. In the mean time, the grapes must move horizontally by s_x at a constant speed of $v_x = 2.2136\,\mathrm{m/s}$, so they must be released a horizontal distance s_x from him, where

$$s_x = v_x t = v_x\sqrt{\frac{2s_y}{g}} = (2.2136\,\mathrm{m/s})\sqrt{\frac{2(1.0000\,\mathrm{m})}{9.8000\,\mathrm{m/s^2}}} = 1.0000\,\mathrm{m}\,.$$

4.7

The two persons are pulling each other through the rope with a force of magnitude 100 N. The net force exerted on the person on the left by the the one on the right is 100 N, to the right.

4.8

Horizontally, there is a rightward external force of magnitude 3.0 kN and a leftward external force of 0.50 kN. The net horizontal external force on the truck is then $3.0\,\mathrm{kN} - 0.50\,\mathrm{kN} = 2.5\,\mathrm{kN}$, to the right. Vertically, the net upward force is $2.5\,\mathrm{kN} + 2.5\,\mathrm{kN} = 5.0\,\mathrm{kN}$, while the net downward force is also 5.0 kN. So the net external force in the vertical direction vanishes.

4.9

Since the 100-N force makes an angle of 45° with the positive x-axis, its x-component is $F_{1x} = (100\,\mathrm{N})\cos 45° = 70.7\,\mathrm{N}$, and its y-component is $F_{1y} = (100\,\mathrm{N})\sin 45° = 70.7\,\mathrm{N}$. Similarly, for the 200-N force $F_{2x} = (200\,\mathrm{N})\cos 30° = 173.2\,\mathrm{N}$ and $F_{2y} = (200\,\mathrm{N})\sin 30° = 100\,\mathrm{N}$. Thus the components of the net force $\vec{F}$ are $F_x = F_{1x} + F_{2x} = 70.7\,\mathrm{N} + 173.2\,\mathrm{N} = 243.9\,\mathrm{N}$ and $F_y = F_{1y} + F_{2y} = 70.7\,\mathrm{N} + 100\,\mathrm{N} = 170.7\,\mathrm{N}$. The magnitude of the equivalent single force $\vec{F}$ is then

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(243.9\,\mathrm{N})^2 + (170.7\,\mathrm{N})^2} = 298\,\mathrm{N}\,,$$

and $\vec{F}$ makes an angle θ with the positive x-direction, where

$$\tan\theta = \frac{F_y}{F_x} = \frac{170.7\,\mathrm{N}}{243.9\,\mathrm{N}} = 0.6999\,,$$

which gives $\theta = +35°$.

4.13

The monkey and the dart start their respective motion at the same instant. Note that the monkey falls vertically so its horizontal position does not change. Suppose that it takes a time t for the dart to close the initial horizontal separation between itself and the monkey. Now, if there were no gravity, then the dart would just move along the line-of-sight. Due to the presence of gravity, however, the actual trajectory of the dart falls *below* the original line-of-sight by an amount $\frac{1}{2}gt^2$ by the time the dart reaches the same horizontal position as the monkey. The monkey, meanwhile, also falls vertically from the line-of-sight by exactly the same amount. So after a time t into the flight the dart and the monkey will be at the same *vertical* as well as *horizontal* position. This is why the dart will get the monkey.

4.22

Due to Newton's Third Law, the net forces exerted on the two magnets are equal in magnitude and opposite in direction. The resulting acceleration of each magnet is inversely proportional to its mass. Since the more massive one (with $m = 2.0\,\text{kg}$) has an acceleration of $(10.0\,\text{m/s}^2)$-north, the 1.0-kg mass must have an acceleration in the opposite direction (i.e., due south), of magnitude $(2.0\,\text{kg}/1.0\,\text{kg})(10.0\,\text{m/s}^2) = 20\,\text{m/s}^2$.

4.33

First find the acceleration $a(t)$ of the ball as the second derivative of its displacement $y(t)$ with respect to time:

$$a(t) = \frac{d^2y}{dt^2} = \frac{d}{dt}\left(\frac{dy}{dt}\right) = \frac{d}{dt}\left\{\frac{d}{dt}\left[(4.9\,\text{m/s}^2)t^2\right]\right\} = \frac{d}{dt}\left[(4.9\,\text{m/s}^2)2t\right] = 9.8\,\text{m/s}^2 .$$

The force acting on the ball (of mass $m = 1.0\,\text{kg}$) is then

$$F(t) = m\,a(t) = (1.0\,\text{kg})(9.8\,\text{m/s}^2) = 9.8\,\text{N} .$$

4.34

(a) The force F exerted by the heart causes the body of mass m to undergo an acceleration of a. So $F = ma = (70\,\text{kg})(0.06\,\text{m/s}^2) = 4\,\text{N}$.

(b) When the force F is applied on the body for $\Delta t = 0.10\,\text{s}$, the resulting change in momentum of the body is $\Delta p = F\Delta t = (4\,\text{N})(0.10\,\text{s}) = 0.4\,\text{N·s}$.

4.39

Consider the deceleration process of the bullet of mass m ($= 10\,\text{g} = 0.010\,\text{kg}$). Before deceleration its initial speed is v_0 ($= 200\,\text{m/s}$), and afterwards its final speed v is of course zero. The average speed v_{av} during the process is then $v_{av} = \frac{1}{2}(v_0 + v) = \frac{1}{2}v_0$. The bullet's displacement during the stage, s ($= 20\,\text{cm} = 0.20\,\text{m}$), then satisfies $s = v_{av}\Delta t$, where $\Delta t = s/v_{av} = 2s/v_0 = 2(0.20\,\text{m})/(200\,\text{m/s}) = 0.0020\,\text{s}$ is the time it took for the bullet to stop inside the block. The change in its speed, meanwhile, is $\Delta v = v - v_0 = -v_0 = -200\,\text{m/s}$, where we chose the direction of motion of the bullet as positive. Thus the average acceleration of the bullet is given by $a_{av} = \Delta v/\Delta t = (-200\,\text{m/s})/(0.0020\,\text{s}) = -1.0 \times 10^5\,\text{m/s}^2$, and the corresponding average force F exerted by the block on the bullet is

$$F_{av} = ma_{av} = (0.010\,\text{kg})(-1.0 \times 10^5\,\text{m/s}^2) = -1.0\,\text{kN} .$$

Here once again the minus sign indicates that the force exerted on the bullet was opposite to its direction of motion. According to Newton's Third Law the force exerted by the bullet on the block is $-F = +1.0\,\text{kN}$, pointing in the direction of motion of the bullet.

4.54

The downward weight of the frog of mass m is $F_W = mg = (0.50\,\text{kg})(9.8\,\text{m/s}^2) = 4.9\,\text{N}$. To lift the frog up one must apply an upward force whose magnitude exceeds 4.9 N. When a minimum force (barely greater than 4.9 N) is applied the net force on the frog is virtually zero, meaning that the frog can only be picked up at a very slow and constant speed.

4.57

The mass m of the youngster can be found from her weight F_W: $m = F_W/g$. Since she experiences an average acceleration a_{av}, the force exerted on her by the floor must be

$$F_{av} = ma_{av} = \frac{F_W a_{av}}{g} = \frac{(392.4\,\text{N})(5.00\,\text{m/s}^2)}{9.81\,\text{m/s}^2} = 200\,\text{N}.$$

4.65

Parallel to the incline, the net force exerted on the car is $\sum F_\parallel = F_W \sin\theta = mg\sin\theta$, where m is the mass of the car and $\theta = 20°$ is the angle of inclination. Set $\sum F_\parallel = ma$ to obtain the acceleration a of the car down the incline: $a = g\sin\theta$. The speed v of the car after sliding down by a distance of $s = 20\,\text{m}$ is then given by $v^2 = 2as$, or

$$v = \sqrt{2as} = \sqrt{2gs\sin\theta} = \sqrt{2(9.81\,\text{m/s}^2)(20\,\text{m})(\sin 20°)} = 12\,\text{m/s}.$$

4.66

(a) The tension F_T on the topmost end of the rope is used to support the weight of both Jamey (J) and Amy (A), who are undergoing no acceleration. Thus

$$F_T = m_J g + m_A g = (100\,\text{kg} + 50.0\,\text{kg})(9.81\,\text{m/s}^2) = 1.47\,\text{kN}.$$

(b) The middle point of the rope has only the weight of Jamey to support. So the tension there is

$$F_T = m_J g = (100\,\text{kg} + 50.0\,\text{kg})(9.81\,\text{m/s}^2) = 981\,\text{N}.$$

(c) The net upward force exerted on the two-people system is F_T, the tension at the topmost of the rope; and the net downward force is their total weight, $F_W = (m_J + m_A)g$. Taking up as positive, Newton's Second Law for the two-people system reads

$$+\uparrow \sum F_y = F_T - (m_J + m_A)g = (m_J + m_A)a,$$

where $a = +9.8\,\text{m/s}^2$. Solve for F_T:

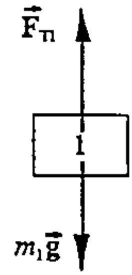
$$F_T = (m_J + m_A)(g + a) = (100\,\text{kg} + 50.0\,\text{kg})(9.8\,\text{m/s}^2 + 9.81\,\text{m/s}^2) = 2.9\,\text{kN}.$$

To find F_T in the middle of the rope, we just have to realize that here F_T is responsible only for the upward acceleration of Jamey, rather than both Jamey and Amy. Thus we eliminate m_A from the equation above and obtain

$$F_T = m_J(g + a) = (100\,\text{kg})(9.8\,\text{m/s}^2 + 9.81\,\text{m/s}^2) = 2.0\,\text{kN}$$

<u>4.87</u>

(a) and (b) Free-body diagrams for the three masses are shown to the right. Since $m_1 > m_3$, m_1 will move down, m_3 will move up, while m_2 will move to the right. Taking up to be positive and denoting the common magnitude of the acceleration for all three masses as a, then Newton's Second Law reads

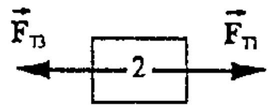


$$+\uparrow \sum F_{y1} = F_{T1} - m_1 g = m_1(-a) = -m_1 a$$

for m_1;

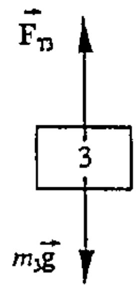
$$\overset{+}{\rightarrow} \sum F_{x2} = F_{T1} - F_{T3} = m_2 a$$

for m_2; and



$$+\uparrow \sum F_{y3} = F_{T3} - m_3 g = m_3 a$$

for m_3. Adding up the last two equations and then subtracting from the result the first equation enables us to eliminate F_{T1} and F_{T3}. The result is $m_1 g - m_3 g = (m_1 + m_2 + m_3)a$, which yields



$$a = \left(\frac{m_1 - m_3}{m_1 + m_2 + m_3}\right) g = \left(\frac{4\,\text{kg} - 2\,\text{kg}}{4\,\text{kg} + 2\,\text{kg} + 2\,\text{kg}}\right) g = \frac{1}{4} g .$$

Now plug in the result of a into the equation for m_1 to find F_{T1}:

$$F_{T1} = m_1 g - m_1 a = m_1 g - \frac{1}{4} m_1 g = \frac{3}{4}(4\,\text{kg})(9.81\,\text{m/s}^2) = 0.3 \times 10^2\,\text{N} = 0.03\,\text{kN};$$

and plug in the result of a into the equation for m_3 to find F_{T3}:

$$F_{T3} = m_3 g + m_3 a = m_3 g + \frac{1}{4} m_3 g = \frac{3}{4}(2\,\text{kg})(9.81\,\text{m/s}^2) = 0.2 \times 10^2\,\text{N} = 0.02\,\text{kN}.$$

(c) The tensions in the ropes are internal to the three-mass system, while the weights of the masses are external.

<u>4.96</u>

To drag the garbage can of weight F_W at a uniform speed (i.e., with zero acceleration), you must apply a force F which is equal to its kinetic friction with the road: $F = F_f = \mu_k F_N = \mu_k F_W \propto F_W$. So as the weight of the can (F_W) increases from 100 N to 150 N the corresponding force should also increase by the same proportion, from 40 N to F', where $F'/40\,\text{N} = 150\,\text{N}/100\,\text{N}$. So $F' = 60\,\text{N}$.

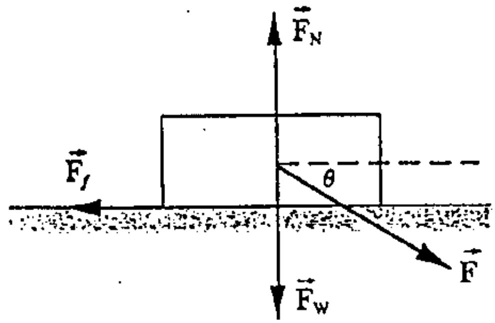
4.102

First, find the acceleration of the bottle. Since the bottle (of mass m) slides up the incline, the kinetic friction on the bottle is down the incline. Perpendicular to the incline the acceleration of the bottle is zero: $a_\perp = 0$. So $+\nearrow \sum F_\perp = F_N - F_W \cos\theta = ma_\perp = 0$, where $\theta = 20°$. Parallel to the incline $+\nwarrow \sum F_\parallel = -F_W \sin\theta - F_f = ma_\parallel$, where the minus signs indicate that the directions of both F_f and the component of gravitational force are down the incline. The first equation above gives $F_N = F_W \cos\theta = mg\cos\theta$, which, when substituted into the second equation, yields $-F_W \sin\theta - F_f = -mg\sin\theta - \mu_k mg\cos\theta = ma_\parallel$, or $a_\parallel = -g(\sin\theta + \mu_k\cos\theta)$. Suppose that the bottle can slide up the incline by a displacement of $s_\parallel$, while its speed decreases from v_0 $(= 2.0\,\mathrm{m/s})$ to v $(= 1.0\,\mathrm{m/s})$, then $v^2 - v_0^2 = 2a_\parallel s_\parallel$, and so

$$\begin{aligned} s_\parallel &= \frac{v^2 - v_0^2}{2a_\parallel} = \frac{v^2 - v_0^2}{-2g(\sin\theta + \mu_k\cos\theta)} \\ &= \frac{(1.0\,\mathrm{m/s})^2 - (2.0\,\mathrm{m/s})^2}{-2(9.81\,\mathrm{m/s^2})\,[\sin 20° + 0.4(\cos 20°)]} \\ &= 0.2\,\mathrm{m}\,. \end{aligned}$$

4.104

A free-body diagram for the trunk of mass m is shown to the right. The force exerted by the woman is denoted as F, which points at $\theta = 30°$ below the horizontal level. In the vertical direction there is no acceleration, so



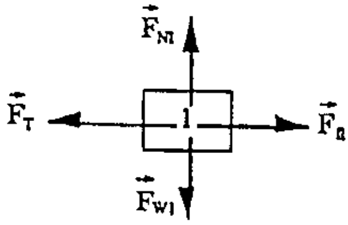
$$+\uparrow \sum F_y = F_N - F\sin\theta - F_W = ma_y = 0\,,$$

where $F_W = mg$. This gives $F_N = F\sin\theta + mg = (300\,\mathrm{N})(\sin 30°) + (100\,\mathrm{kg})(9.81\,\mathrm{m/s^2}) = 1.13\,\mathrm{kN}$.

In the horizontal direction, in order for the trunk to slide forward the woman needs to first overcome the maximum static friction from the floor: $F_f(\max) = \mu_s F_N = (0.5)(1.13\,\mathrm{kN}) = 565\,\mathrm{N}$. However, the force to the right is only $F\cos\theta = (300\,\mathrm{N})(\cos 30°) = 260\,\mathrm{N}$, which is less than the 565-N force needed. So the trunk will not move, and its acceleration is of course zero.

4.108

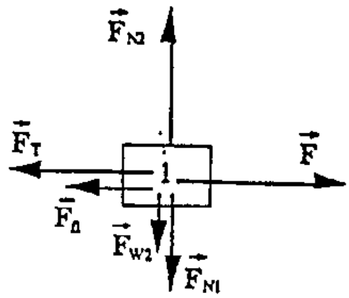
Free-body diagrams for both m_1 and m_2 are shown to the right. The tension F_T exerted by the rope on both masses is the same, since the rope is massless. Neither mass is undergoing any acceleration. So for m_1



$$+\uparrow \sum F_{y1} = F_{N1} - F_{W1} = m_1 a_{y1} = 0$$

and

$$\overset{+}{\rightarrow} \sum F_{x1} = F_{f1} - F_T = m_1 a_{x1} = 0\,,$$



where $F_{f1} = \mu_k F_{N1}$. These equations yield $F_T = F_{f1} = \mu_k F_{N1} = \mu_k F_{W1}$. Similarly, for m_2

$$+\uparrow \sum F_{y2} = F_{N2} - F_{N1} - F_{W2} = m_2 a_{y2} = 0$$

and

$$\overset{+}{\rightarrow} \sum F_{x2} = F - F_{f1} - F_{f2} - F_T = m_2 a_{x2} = 0\,,$$

where $F_{f2} = \mu_k F_{N2}$. The equation for F_{y2} yields $F_{N2} = F_{N1} + F_{W2} = F_{W1} + F_{W2}$, which we substitute into the one for F_{x2}, together with $F_{f1} = F_T = \mu_k F_{W1}$, to solve for F:

$$\begin{aligned} F &= F_{f1} + F_{f2} + F_T = \mu_k F_{W1} + \mu_k F_{N2} + \mu_k F_{W1} = \mu_k F_{W1} + \mu_k (F_{W1} + F_{W2}) + \mu_k F_{W1} \\ &= \mu_k (3F_{W1} + F_{W2}) \\ &= (0.40)(3 \times 5.0\,\mathrm{N} + 10\,\mathrm{N}) \\ &= 10\,\mathrm{N}\,. \end{aligned}$$

4.113

Let the tension in the upper rope be F_{TU} and that in the lower one be F_{TL}. The lower mass (L) is subject to two forces: F_{TL}, upward; and $F_{WL} = m_L g$, downward. Here $m_L = 10\,\mathrm{kg}$. Inasmuch as $a_L = 0$ $\quad +\uparrow \sum F_{yL} = F_{TL} - F_{WL} = m_L a_L = 0$, so

$$F_{TL} = F_{WL} = m_L g = (10\,\mathrm{kg})(9.81\,\mathrm{m/s^2}) = 98\,\mathrm{N}\,.$$

Similarly, for the upper mass (U) $\quad +\uparrow \sum F_{yU} = F_{TU} - F_{TL} - F_{WU} = m_U a_U = 0$, so

$$F_{TU} = F_{WU} + F_{TL} = m_U g + F_{TL} = (10\,\mathrm{kg})(9.81\,\mathrm{m/s^2}) + 98\,\mathrm{N} = 2.0 \times 10^2\,\mathrm{N} = 0.20\,\mathrm{kN}\,.$$

4.114

(a) The tension at any given location of the rope has to support the weight of the portion of the rope which is below that particular location. At three-quarters (3/4) of the way up the rope the weight to be supported is $F_W = (3/4)(20\,\mathrm{m})(2.0\,\mathrm{N/m}) = 30\,\mathrm{N}$, so the tension there is $F_T = 30\,\mathrm{N}$.

(b) At 1.0 m from the top there are still $20\,\mathrm{m} - 1.0\,\mathrm{m} = 19\,\mathrm{m}$ of the rope whose weight has to be supported. So the tension there is $F_T = (19\,\mathrm{m})(2.0\,\mathrm{N/m}) = 38\,\mathrm{N}$.

4.116

The net force exerted on the tooth by the tension of the wire brace is

$$F = 2F_T \cos 80.0° = 2(10.0\,\mathrm{N})(\cos 80.0°) = 3.47\,\mathrm{N}\,,$$

pointing inward along the perpendicular direction. Here the factor of 2 is due to the fact there are *two* tensions, as shown in Fig. P116, one pointing to the left and the other to the right of the tooth. Note that the net force in the direction parallel to the wire is zero because of symmetry.

4.120

(a) If the force applied by the hand be F, then the tension throughout the entire massless rope is $F_T = F$. Consider the balance of forces for the lower pulley. It is subject to two upward tensions of F_T each and a downward force of 300 N. So $+\uparrow\sum F_y = 2F_T - 300\,\mathrm{N} = 0$, which yields $F = F_T = 150\,\mathrm{N}$.

(b) Since the rope is massless the tension in any segment of the rope is always the same, at $F_T = 150\,\mathrm{N}$.

(c) Each of the three segments of the rope exerts a downward force of $F_T = 150\,\mathrm{N}$ on the upper hook through the upper pulley. Thus the upward supporting force F_U on the hook has to balance these three tensions: $F_U = 3F_T = 3(150\,\mathrm{N}) = 450\,\mathrm{N}$.

4.126

Denote the angle the rope makes with the horizontal as θ on both sides of the 100-N mass. Then $\tan\theta = 10\,\mathrm{cm}/(2.0\,\mathrm{m}/2) = 0.10$, so $\theta = 5.71°$. Let the tension in the rope be F_T. Consider the midpoint of the horizontal rope, where the hook is located. Again, by symmetry we see that the net horizontal force exerted on it is zero. In the vertical direction, this point is subject to a downward force of $F_W = 100\,\mathrm{N}$, while it is being pulled up by the rope on both sides, with a total upward force of $2F_T \sin\theta$. Thus for the midpoint $+\uparrow\sum F_y = 2F_W \sin\theta - F_W$, which yields

$$F_T = \frac{F_T}{2\sin\theta} = \frac{100\,\mathrm{N}}{2(\sin 5.71°)} = 5.0\times 10^2\,\mathrm{N} = 0.50\,\mathrm{kN}\,.$$

This is the reading of the scale.

4.127

Follow the analysis of the previous problem. For the point on the wire just below the feet of the tightrope walker

$$+\uparrow\sum F_y = 2F_T \sin\theta - F_W\,,$$

where F_T is the tension in the wire, $F_W = 533.8\,\mathrm{N}$ is her weight, and $\theta = 5.0°$. Hence

$$F_T = \frac{F_W}{2\sin\theta} = \frac{533.8\,\mathrm{N}}{2(\sin 5.0°)} = 3.1\times 10^3\,\mathrm{N} = 3.1\,\mathrm{kN}\,.$$

equation reads $+\uparrow \sum F_y = F_T \sin\theta - F_W = 0$, where $F_W = 2.00\,\text{kN}$. Solve for F_T and F_R from the two equations above to obtain

$$\begin{cases} F_T = \dfrac{F_W}{\sin\theta} = \dfrac{2.00\,\text{kN}}{\sin 45.0^\circ} = 1.41\,\text{kN}, \\ \\ F_R = F_T \cos\theta = \left(\dfrac{F_W}{\sin\theta}\right)\cos\theta = \dfrac{(2.00\,\text{kN})(\cos 45.0^\circ)}{\sin 45.0^\circ} = 2.00\,\text{kN}. \end{cases}$$

4.134

A fly has only a negligible mass compared with any of the three masses in question. For the tiny fly to upset the balance the system must already be on the verge of moving even before it lands on the 80.0-kg mass. This means that the difference in the tensions exerted by the ropes on the 75.0-kg mass in the middle, $\Delta F_T = (80.0\,\text{kg} - 10.0\,\text{kg})g = -(70.0\,\text{kg})g$, is balanced by the maximum static friction $F_f(\text{max})$ exerted on the mass:

$$F_f(\text{max}) = \mu_s(75.0\,\text{kg})g = \Delta F_T = (70.0\,\text{kg})g,$$

which yields

$$\mu_s = \frac{(70.0\,\text{kg})g}{(75.0\,\text{kg})g} = 0.933.$$