PROBLEM SOLUTIONS

4.1 $w = (2\ \cancel{\text{tons}})\left(\dfrac{2000\ \cancel{\text{lbs}}}{1\ \cancel{\text{ton}}}\right)\left(\dfrac{4.448\ \text{N}}{1\ \cancel{\text{lb}}}\right) = \boxed{2 \times 10^4\ \text{N}}$

4.2 From $v = v_0 + a\,t$, the acceleration given to the football is

$$a_{\text{av}} = \frac{v - v_0}{t} = \frac{10\ \text{m/s} - 0}{0.20\ \text{s}} = 50\ \text{m/s}^2$$

Then, from Newton's 2^{nd} law, we find

$$F_{\text{av}} = m\,a_{\text{av}} = (0.50\ \text{kg})(50\ \text{m/s}^2) = \boxed{25\ \text{N}}$$

4.3 (a) $\Sigma F_x = ma_x = (6.0\ \text{kg})(2.0\ \text{m/s}^2) = \boxed{12\ \text{N}}$

(b) $a_x = \dfrac{\Sigma F_x}{m} = \dfrac{12\ \text{N}}{4.0\ \text{kg}} = \boxed{3.0\ \text{m/s}^2}$

4.4 (a) Action: The hand exerts a force to the right on the spring. Reaction: The spring exerts an equal magnitude force to the left on the hand. Action: The wall exerts a force to the left on the spring. Reaction: The spring exerts an equal magnitude force to the right on the wall. Action: Earth exerts an downward gravitational force on the spring. Reaction: The spring exerts an equal magnitude gravitational force upward on the Earth.

(b) Action: The handle exerts a force upward to the right on the wagon. Reaction: The wagon exerts an equal magnitude force downward to the left on the handle. Action: Earth exerts an upward contact force on the wagon. Reaction: The wagon exerts an equal magnitude downward contact force on the Earth. Action: Earth exerts an downward gravitational force on the wagon. Reaction: The wagon exerts an equal magnitude gravitational force upward on the Earth.

(c) Action: The player exerts a force upward to the left on the ball. Reaction: The ball exerts an equal magnitude force downward to the right on the player. Action: Earth exerts an downward gravitational force on the ball. Reaction: The ball exerts an equal magnitude gravitational force upward on the Earth.

(d) Action: *M* exerts a gravitational force to the right on *m*. Reaction: *m* exerts an equal magnitude gravitational force to the left on *M*.

(e) Action: The charge $+Q$ exerts an electrostatic force to the right on the charge $-q$. Reaction: The charge $-q$ exerts an equal magnitude electrostatic force to the left on the charge $+Q$.

(f) Action: The magnet exerts a force to the right on the iron. Reaction: The iron exerts an equal magnitude force to the left on the magnet.

4.5 The weight of the bag of sugar on Earth is

$$w_E = mg_E = 5.00\text{ lbs}\left(\frac{4.448\text{ N}}{1\text{ lb}}\right) = 22.2\text{ N}$$

If g_M is the free-fall acceleration on the surface of the Moon, the ratio of the weight of an object on the Moon to its weight when on Earth is

$$\frac{w_M}{w_E} = \frac{mg_M}{mg_E} = \frac{g_M}{g_E}$$

so

$$w_M = w_E\left(\frac{g_M}{g_E}\right).$$

Hence, the weight of the bag of sugar on the Moon is

$$w_M = 22.2\text{ N}\left(\frac{1}{6}\right) = \boxed{3.71\text{ N}}.$$

On Jupiter, its weight would be

$$w_J = w_E\left(\frac{g_J}{g_E}\right) = 22.2\text{ N}\quad 2.64 = \boxed{58.7\text{ N}}$$

The mass is the same at all three locations, and is given by

$$m = \frac{w_E}{g_E} = \frac{5.00\text{ lb}\quad 4.448\text{ N/lb}}{9.80\text{ m/s}^2} = \boxed{2.27\text{ kg}}$$

4.6

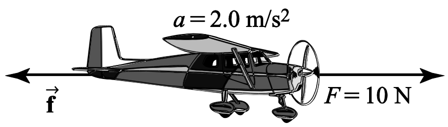
$$a = \frac{\Sigma F}{m} = \frac{7.5\times 10^5\text{ N}}{1.5\times 10^7\text{ kg}} = 5.0\times 10^{-2}\text{ m/s}^2$$

and $v = v_0 + at$ gives

$$t = \frac{v - v_0}{a} = \frac{80\text{ km/h} - 0}{5.0\times 10^{-2}\text{ m/s}^2}\left(\frac{0.278\text{ m/s}}{1\text{ km/h}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = \boxed{7.4\text{ min}}$$

4.7 Summing the forces on the plane shown gives

$$\Sigma F_x = ma_x \quad \Rightarrow \quad 10\text{ N} - f = \left(0.20\text{ kg}\right)\left(2.0\text{ m/s}^2\right)$$



From which, $f = \boxed{9.6\text{ N}}$

4.8 (a) The sphere has a larger mass than the feather. Hence, the sphere experiences a larger gravitational force $F_g = mg$ than does the feather.

(b) The time of fall is less for the sphere than for the feather. This is because air resistance affects the motion of the feather more than that of the sphere.

(c) In a vacuum, the time of fall is the same for the sphere and the feather. In the absence of air resistance, both objects have the free-fall acceleration g.

(d) In a vacuum, the total force on the sphere is greater than that on the feather. In the absence of air resistance, the total force is just the gravitational force, and the sphere weighs more than the feather.

4.9 The vertical acceleration of the salmon as it goes from $v_{0y} = 3.0\text{ m/s}$ (underwater) to $v_y = 6.0\text{ m/s}$ (after moving upward 1.0 m or 2/3 of its body length) is

$$a_y = \frac{v_y^2 - v_{0y}^2}{2\left(\Delta y\right)} = \frac{\left(6.0\text{ m/s}\right)^2 - \left(3.0\text{ m/s}\right)^2}{2\left(1.00\text{ m}\right)} = 13.5\text{ m/s}^2$$

Applying Newton's second law to the vertical leap of this salmon having a mass of 61 kg, we find

$$\Sigma F_y = ma_y \quad \Rightarrow \quad F - mg = ma_y$$

or

$$F = m\left(a_y + g\right) = \left(61\text{ kg}\right)\left(13.5\ \frac{\text{m}}{\text{s}^2} + 9.8\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{1.4 \times 10^3\text{ N}}$$

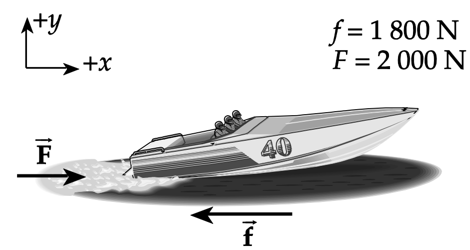
4.10 The acceleration of the bullet is given by

$$a = \frac{v^2 - v_0^2}{2\ \Delta x} = \frac{320\ \text{m/s}^{\ 2} - 0}{2\ 0.82\ \text{m}}$$

Then,

$$\Sigma F = ma = 5.0 \times 10^{-3}\ \text{kg}\left[\frac{320\ \text{m/s}^{\ 2}}{2\ 0.82\ \text{m}}\right] = \boxed{3.1 \times 10^2\ \text{N}}$$

4.11 (a) From the second law, the acceleration of the boat is



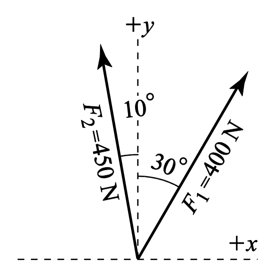
$$a = \frac{\Sigma F}{m} = \frac{2\ 000\ \text{N} - 1\ 800\ \text{N}}{1\ 000\ \text{kg}} = \boxed{0.200\ \text{m/s}^2}$$

(b) The distance moved is

$\Delta x = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}\ 0.200\ \text{m/s}^2\ \ 10.0\ \text{s}^{\ 2} = \boxed{10.0\ \text{m}}$

(c) The final velocity is## $v = v_0 + at = 0 + 0.200\ \text{m/s}^2\ \ 10.0\ \text{s} = \boxed{2.00\ \text{m/s}}$.

4.12 (a) Choose the positive y-axis in the forward direction. We resolve the forces into their components as



Force	***x*-component**	***y*-component**
400 N	200 N	346 N
450 N	–78.1 N	443 N
Resultant	$\Sigma F_x = 122$ N	$\Sigma F_y = 790$ N

The magnitude and direction of the resultant force is

$$F_R = \sqrt{\Sigma F_x^{\ 2} + \Sigma F_y^{\ 2}} = 799\ \text{N} \qquad \theta = \tan^{-1}\left(\frac{\Sigma F_x}{\Sigma F_y}\right) = 8.77°\ \text{to right of } y\text{-axis}$$

Thus, $\boxed{\vec{\mathbf{F}}_R = 799\ \text{N at } 8.77° \text{ to the right of the forward direction}}$

(b) The acceleration is in the same direction as $\vec{\mathbf{F}}_R$ and has magnitude

$$a = \frac{F_R}{m} = \frac{799\ \text{N}}{3\ 000\ \text{kg}} = \boxed{0.266\ \text{m/s}^2}$$

4.13 (a) At terminal speed, the magnitude of the air resistance force is equal to the weight of the skydiver $F_{drag} = mg$. Therefore,

$$k = \frac{F_{drag}}{v^2} = \frac{mg}{v_{terminal}^2} = \frac{(65.0\ \text{kg})(9.80\ \text{m/s}^2)}{(55.0\ \text{m/s})^2} = \boxed{0.211\ \text{kg/m}}$$

(b) At the speed $v = \frac{1}{2} v_{terminal}$, the upward force due to air resistance is less than the downward gravitational force acting on the skydiver, leaving a net downward force of magnitude $F_{net} = mg - F_{drag}$. Thus, the skydiver will have a downward acceleration of magnitude

$$a = \frac{F_{net}}{m} = \frac{mg - kv^2}{m} = g - \left(\frac{k}{m}\right)\left(\frac{v_{terminal}}{2}\right)^2$$
$$= 9.80\ \text{m/s}^2 - \left(\frac{0.211\ \text{kg/m}}{65.0\ \text{kg}}\right)\left(\frac{55.0\ \text{m/s}}{2}\right)^2 = \boxed{7.35\ \text{m/s}^2}$$

4.14 (a) With the wind force being horizontal, the only vertical force acting on the object is its own weight, mg. This gives the object a downward acceleration of

$$a_y = \frac{\Sigma F_y}{m} = \frac{-mg}{m} = -g$$

The time required to undergo a vertical displacement $\Delta y = -h$, starting with initial vertical velocity $v_{0y} = 0$, is found from $\Delta y = v_{0y}t + \frac{1}{2} a_y t^2$ as

$$-h = 0 - \frac{g}{2} t^2 \qquad \text{or} \qquad \boxed{t = \sqrt{\frac{2h}{g}}}$$

(b) The only horizontal force acting on the object is that due to the wind, so $\Sigma F_x = F$ and the horizontal acceleration will be $a_x = \dfrac{\Sigma F_x}{m} = \boxed{\dfrac{F}{m}}$

(c) With $v_{0x} = 0$, the horizontal displacement the object undergoes while falling a vertical distance h is given by $\Delta x = v_{ox}t + \frac{1}{2} a_x t^2$ as

$$\Delta x = 0 + \frac{1}{2}\left(\frac{F}{m}\right)\left(\sqrt{\frac{2h}{g}}\right)^2 = \boxed{\frac{Fh}{mg}}$$

(d) The total acceleration of this object while it is falling will be

$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{F/m^{\ 2} + \ -g^{\ 2}} = \boxed{\sqrt{F/m^{\ 2} + g^2}}$$

4.15 Starting with $v_{0y} = 0$ and falling 30 m to the ground, the velocity of the ball just before it hits is

$$v_1 = -\sqrt{v_{0y}^2 + 2a_y\Delta y} = -\sqrt{0 + 2 \ \ -9.80 \ \text{m/s}^2 \ \ \ -30 \ \text{m}} = -24 \ \text{m/s}$$

On the rebound, the ball has $v_y = 0$ after a displacement $\Delta y = +20$ m. Its velocity as it left the ground must have been

$$v_2 = +\sqrt{v_y^2 - 2a_y\Delta y} = +\sqrt{0 - 2 \ \ -9.80 \ \text{m/s}^2 \ \ \ 20 \ \text{m}} = +20 \ \text{m/s}$$

Thus, the average acceleration of the ball during the 2.0-ms contact with the ground was

$$a_{\text{av}} = \frac{v_2 - v_1}{\Delta t} = \frac{+20 \ \text{m/s} - \ -24 \ \text{m/s}}{2.0 \times 10^{-3} \ \text{s}} = +2.2 \times 10^4 \ \text{m/s}^2 \qquad \text{upward}$$

The average resultant force acting on the ball during this time interval must have been

$$F_{net} = ma_{\text{av}} = \ 0.50 \ \text{kg} \ \ +2.2 \times 10^4 \ \text{m/s}^2 \ = +1.1 \times 10^4 \ \text{N}$$

or

$$\vec{\mathbf{F}}_{net} = \boxed{1.1 \times 10^4 \ \text{N upward}}$$

4.16 Since the two forces are perpendicular to each other, their resultant is:

$$F_R = \sqrt{\ 180 \ \text{N}^{\ 2} + \ 390 \ \text{N}^{\ 2}} = 430 \ \text{N}, \text{ at } \theta = \tan^{-1}\left(\frac{390 \ \text{N}}{180 \ \text{N}}\right) = 65.2° \text{ N of E}$$

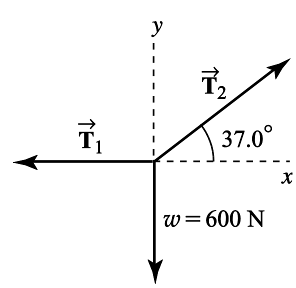
Thus,

$$a = \frac{F_R}{m} = \frac{430 \ \text{N}}{270 \ \text{kg}} = 1.59 \ \text{m/s}^2$$

or

$$\vec{\mathbf{a}} = \boxed{1.59 \ \text{m/s}^2 \ \text{at } 65.2° \text{ N of E}}.$$

4.17 (a) Since the burglar is held in equilibrium, the tension in the vertical cable equals the burglar's weight of $\boxed{600 \ \text{N}}$ Now, consider the junction in the three cables:##



$\Sigma F_y = 0$, giving $T_2 \sin 37.0° - 600 \ \text{N} = 0$

or

$$T_2 = \frac{600\text{ N}}{\sin 37.0°} = \boxed{997\text{ N in the inclined cable}}$$

Also, $\Sigma F_x = 0$ which yields $T_2 \cos 37.0° - T_1 = 0$, or

$$T_1 = (997\text{ N})\cos 37.0° = \boxed{796\text{ N in the horizontal cable}}$$

$$\boxed{\text{decreasing the tension in the cable on the right}}$$

(b) If the left end of the originally horizontal cable was attached to a point higher up the wall, the tension in this cable would then have an upward component. This upward component would support part of the weight of the cat burglar, thus.

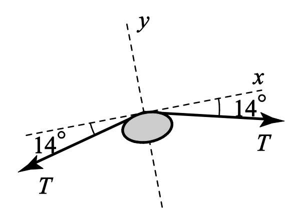
4.18 Using the reference axis shown in the sketch at the right, we see that

$$\Sigma F_x = T\cos 14.0° - T\cos 14.0° = 0$$

and

$$\Sigma F_y = -T\sin 14.0° - T\sin 14.0° = -2T\sin 14.0°$$

Thus, the magnitude of the resultant force exerted on the tooth by the wire brace is



$$R = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2} = \sqrt{0 + (-2T\sin 14.0°)^2} = 2T\sin 14.0°$$

or

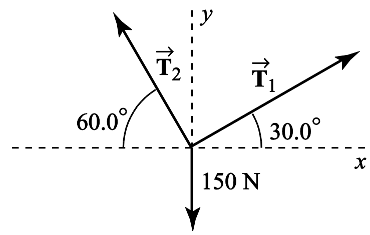
$$R = 2(18.0\text{ N})\sin 14.0° = \boxed{8.71\text{ N}}$$

4.19 From $\Sigma F_x = 0$, $T_1 \cos 30.0° - T_2 \cos 60.0° = 0$

or $\quad T_2 = 1.73\ T_1 \qquad$ [1]

Then $\Sigma F_y = 0$ becomes

$$T_1 \sin 30.0° + 1.73\ T_1\ \sin 60.0° - 150\ \text{N} = 0$$



which gives $T_1 = \boxed{75.0\ \text{N in the right side cable}}$.

Finally, Equation [1] above gives

$T_2 = \boxed{130\ \text{N in the left side cable}}$.

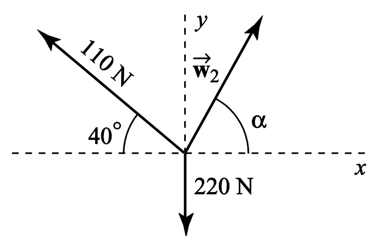
4.20 If the hip exerts no force on the leg, the system must be in equilibrium with the three forces shown in the free-body diagram.

Thus $\Sigma F_x = 0$ becomes

$$w_2 \cos\alpha = 110\ \text{N}\ \cos 40° \qquad [1]$$

From $\Sigma F_y = 0$, we find

$$w_2 \sin\alpha = 220\ \text{N} - 110\ \text{N}\ \sin 40° \qquad [2]$$



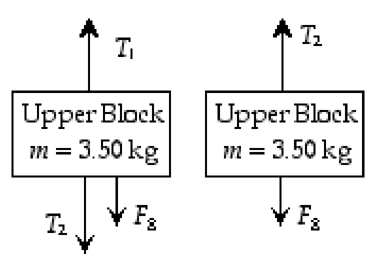
Dividing Equation [2] by Equation [1] yields

$$\alpha = \tan^{-1}\left(\frac{220\ \text{N} - 110\ \text{N}\ \sin 40°}{110\ \text{N}\ \cos 40°}\right) = \boxed{61°}$$

Then, from either Equation [1] or [2], $w_2 = \boxed{1.7\times10^2\ \text{N}}$.

4.21 (a) Free-body diagrams of the two blocks are shown at the right. Note that each block experiences a downward gravitational force

$$F_g = 3.50\ \text{kg}\ \ 9.80\ \text{m/s}^2 = 34.3\ \text{N}$$



Also, each has the same upward acceleration as the elevator, in this case $a_y = +1.60\ \text{m/s}^2$.

Applying Newton's second law to the lower block:

$$\Sigma F_y = ma_y \quad \Rightarrow \quad T_2 - F_g = ma_y$$

or $$T_2 = F_g + ma_y = 34.3 \text{ N} + \;\; 3.50 \text{ kg} \;\; 1.60 \;\text{ m/s}^2 \;\; = \boxed{39.9 \text{ N}}$$

Next, applying Newton's second law to the upper block:

$$\Sigma F_y = ma_y \quad \Rightarrow \quad T_1 - T_2 - F_g = ma_y$$

or

$$T_1 = T_2 + F_g + ma_y = 39.9 \text{ N} + 34.3 \text{ N} + \;\; 3.50 \text{ kg} \;\; 1.60 \;\text{ m/s}^2 \;\; = \boxed{79.8 \;\; \text{N}}$$

(b) Note that the tension is greater in the upper string, and this string will break first as the acceleration of the system increases. Thus, we wish to find the value of a_y when $T_1 = 85.0 \text{ N}$. Making use of the general relationships derived in (a) above gives:

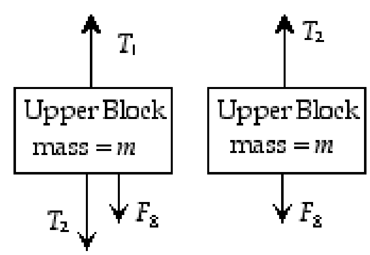
$$T_1 = T_2 + F_g + ma_y = \;\; F_g + ma_y \;\; + F_g + ma_y = 2F_g + 2ma_y$$

or

$$a_y = \frac{T_1 - 2F_g}{2m} = \frac{85.0 \text{ N} - 2 \;\; 34.3 \text{ N}}{2 \;\; 3.50 \text{ kg}} = \boxed{2.34 \;\; \text{m/s}^2}$$

4.22 (a) Free-body diagrams of the two blocks are shown at the right. Note that each block experiences a downward gravitational force $F_g = mg$.

Also, each has the same upward acceleration as the elevator, $a_y = +a$.



Applying Newton's second law to the lower block:

$$\Sigma F_y = ma_y \quad \Rightarrow \quad T_2 - F_g = ma_y \quad \text{or} \quad T_2 = mg + ma = \boxed{m \;\; g + a}$$

Next, applying Newton's second law to the upper block:

$$\Sigma F_y = ma_y \quad \Rightarrow \quad T_1 - T_2 - F_g = ma_y$$

or

$$T_1 = T_2 + F_g + ma_y = \;\; mg + ma \;\; + mg + ma = 2 \;\; mg + ma \;\; = \boxed{2T_1}$$

(b) Note that $\boxed{T_1 = 2T_2\text{, so the upper string breaks first}}$ as the acceleration of the system increases.

(c) When the upper string breaks, both blocks will be in free-fall with $a = -g$. Then, using the results of part (a), $T_2 = m(g + a) = m(g - g) = \boxed{0}$ and $T_1 = 2T_2 = \boxed{0}$.

4.23 $m = 1.00 \text{ kg}$ and $mg = 9.80 \text{ N}$

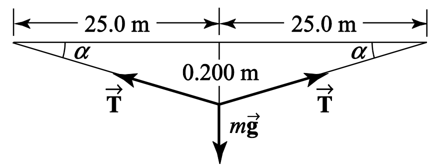
$$\alpha = \tan^{-1}\left(\frac{0.200 \text{ m}}{25.0 \text{ m}}\right) = 0.458°$$

Since $a_y = 0$, require that $\Sigma F_y = T\sin\alpha + T\sin\alpha - mg = 0$,

giving $2T\sin\alpha = mg$,

or

$$T = \frac{9.80 \text{ N}}{2\sin\alpha} = \boxed{613 \text{ N}}$$



4.24 The resultant force exerted on the boat by the people is

$$2\left[(600 \text{ N})\cos 30.0°\right] = 1.04 \times 10^3 \text{ N in the forward direction}$$

If the boat moves with constant velocity, the total force acting on it must be zero. Hence, the resistive force exerted on the boat by the water must be

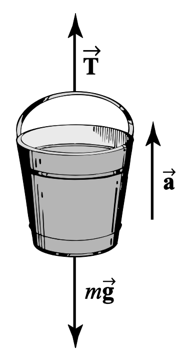
$$\vec{\mathbf{f}} = \boxed{1.04 \times 10^3 \text{ N in the rearward direction}}$$

4.25 The forces on the bucket are the tension in the rope and the weight of the bucket, $mg = (5.0 \text{ kg})(9.80 \text{ m/s}^2) = 49 \text{ N}$. Choose the positive direction upward and use Newton's second law:

$$\Sigma F_y = ma_y$$

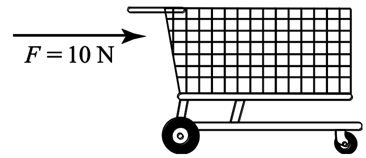
$$T - 49 \text{ N} = (5.0 \text{ kg})(3.0 \text{ m/s}^2)$$

$$T = \boxed{64 \text{ N}}$$



4.26 (a) From Newton's second law, we find the acceleration as

$$a_x = \frac{\Sigma F_x}{m} = \frac{10\text{ N}}{30\text{ kg}} = 0.33\ \text{m/s}^2$$



To find the distance moved, we use

$$\Delta x = v_{0x}t + \frac{1}{2}a_x t^2 = 0 + \frac{1}{2}\ 0.33\ \text{m/s}^2\quad 3.0\text{ s}^{\ 2} = \boxed{1.5\text{ m}}$$

(b) If the shopper places her $30\text{ N}\quad 3.1\text{ kg}$ child in the cart, the new acceleration will be

$$a_x = \frac{\Sigma F_x}{m_{total}} = \frac{10\text{ N}}{33\text{ kg}} = 0.30\ \text{m/s}^2$$

and the new distance traveled in 3.0 s will be

$$\Delta x' = 0 + \frac{1}{2}\ 0.30\ \text{m/s}^2\quad 3.0\text{ s}^{\ 2} = \boxed{1.4\text{ m}}$$

4.27 (a) The average acceleration is given by

$$a_{\text{av}} = \frac{v - v_0}{\Delta t} = \frac{5.00\ \text{m/s} - 20.0\ \text{m/s}}{4.00\text{ s}} = -3.75\ \text{m/s}^2$$

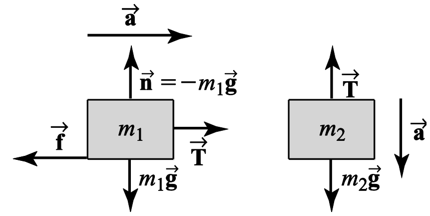
The average force is found from Newton's second law as

$$F_{\text{av}} = ma_{\text{av}} = 2000\text{ kg}\quad -3.75\ \text{m/s}^2 = \boxed{-7.50 \times 10^3\text{ N}}$$

(b) The distance traveled is:

$$x = v_{\text{av}}\ \Delta t = \left(\frac{5.00\ \text{m/s} + 20.0\ \text{m/s}}{2}\right)\ 4.00\text{ s} = \boxed{50.0\text{ m}}$$

4.28 Let $m_1 = 10.0\text{ kg}$, $m_2 = 5.00\text{ kg}$, and $\theta = 40.0°$.



Applying the second law to each object gives

$$m_1 a = m_1 g - T \qquad [1]$$

and

$$m_2 a = T - m_2\, g \sin\theta \qquad [2]$$

Adding these equations yields

$$m_1 a + m_2 a = m_1 g - \cancel{T} + \cancel{T} - m_2 g \quad \text{or} \quad a = \left(\frac{m_1 - m_2 \sin\theta}{m_1 + m_2}\right) g$$

so

$$a = \left(\frac{10.0\text{ kg} - 5.00\text{ kg}\ \sin 40.0°}{15.0\text{ kg}}\right) 9.80\ \text{m/s}^2 = \boxed{4.43\ \text{m/s}^2}$$

Then, Equation [1] yields

$$T = m_1\ g - a = 10.0\text{ kg}\left[\ 9.80 - 4.43\quad \text{m/s}^2\right] = \boxed{53.7\text{ N}}$$

4.29 (a) The resultant external force acting on this system, consisting of all three blocks having a total mass of 6.0 kg, is 42 N directed horizontally toward the right. Thus, the acceleration produced is

$$a = \frac{\Sigma F}{m} = \frac{42\text{ N}}{6.0\text{ kg}} = \boxed{7.0\ \text{m/s}^2 \text{ horizontally to the right}}$$

(b) Draw a free body diagram of the 3.0-kg block and apply Newton's second law to the horizontal forces acting on this block:

$$\Sigma F_x = ma_x \Rightarrow 42\text{ N} - T = 3.0\text{ kg}\quad 7.0\ \text{m/s}^2\ \text{, and therefore } T = \boxed{21\text{ N}}$$

(c) The force accelerating the 2.0-kg block is the force exerted on it by the 1.0-kg block. Therefore, this force is given by: $F = ma = 2.0\text{ kg}\quad 7.0\ \text{m/s}^2$, or

$\vec{\mathbf{F}} = \boxed{\text{14 N horizontally to the right}}$.

4.30 The acceleration of the mass down the incline is given by

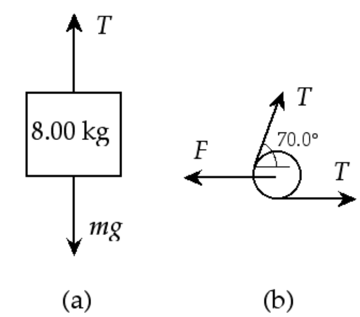
$$\Delta x = v_0 t + \frac{1}{2} a\, t^2, \qquad \text{or} \qquad 0.80\ \text{m} = 0 + \frac{1}{2} a\ \ 0.50\ \text{s}^{\ 2}$$

This gives

$$a = \frac{2\ \ 0.80\ \text{N}}{0.50\ \text{s}^{\ 2}} = 6.4\ \ \text{m/s}^2$$

Thus, the net force directed down the incline is $F = ma = \ 2.0\ \text{kg}\ \ \ 6.4\ \ \text{m/s}^2\ \ = \boxed{13\ \text{N}}$.

4.31 (a) Assuming frictionless pulleys, the tension is uniform through the entire length of the rope. Thus, the tension at the point where the rope attaches to the leg is the same as that at the 8.00-kg block. Part (a) of the sketch at the right gives a free-body diagram of the suspended block. Recognizing that the block has zero acceleration, Newton's second law gives



$$\Sigma F_y = T - mg = 0$$

or

$$T = mg = \ 8.00\ \text{kg}\ \ \ 9.80\ \ \text{m/s}^2\ \ = \boxed{78.4\ \text{N}}$$

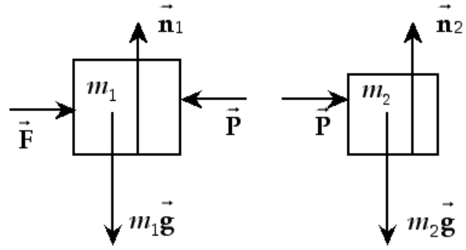
(b) Part (b) of the sketch above gives a free-body diagram of the pulley near the foot. Here, F is the magnitude of the force the foot exerts on the pulley. By Newton's third law, this is the same as the magnitude of the force the pulley exerts on the foot. Applying the second law gives:

$$\Sigma F_x = T + T\cos 70.0° - F = ma_x = 0$$

or

$$F = T\ \ 1 + \cos 70.0°\ \ = \ 78.4\ \text{N}\ \ \ 1 + \cos 70.0°\ \ = \boxed{105\ \text{N}}$$

4.32 (a)



(b) Note that the blocks move on a horizontal surface with $a_y = 0$. Thus, the net vertical force acting on each block and on the combined system of both blocks is zero. The net horizontal force acting on the combined system consisting of both m_1 and m_2 is $\Sigma F_x = F - P + P = \boxed{F}$.

(c) Looking at just m_1, $\Sigma F_y = 0$ as explained above, while $\Sigma F_x = \boxed{F - P}$.

(d) Looking at just m_2, we again have $\Sigma F_y = 0$, while $\Sigma F_x = \boxed{+P}$

(e) For m_1: $\Sigma F_x = ma_x \quad \Rightarrow \quad \boxed{F - P = m_1 a}$.

For m_2: $\Sigma F_x = ma_x \quad \Rightarrow \quad \boxed{P = m_2 a}$.

(f) Substituting the second of the equations found in (e) above into the first gives the following:

$$m_1 a = F - P = F - m_2 a \qquad \text{or} \qquad (m_1 + m_2)a = F \qquad \text{and} \qquad \boxed{a = F/(m_1 + m_2)}$$

Then substituting this result into the second equation from (e), we have

$$P = m_2 a = m_2\left(\frac{F}{m_1 + m_2}\right) \qquad \text{or} \qquad \boxed{P = \left(\frac{m_2}{m_1 + m_2}\right)F}$$

(g) Realize that applying the force to m_2 rather than m_1 would have the effect of interchanging the roles of m_1 and m_2. We may easily find the results for that case by simply interchanging the labels m_1 and m_2 in the results found in (f) above. This gives $a = F/(m_2 + m_1)$ (the same result as in the first case) and $\boxed{P = \left(\frac{m_1}{m_2 + m_1}\right)F}$

We see that

$\boxed{\text{the contact force, } P\text{, is larger in this case because } m_1 > m_2}$.

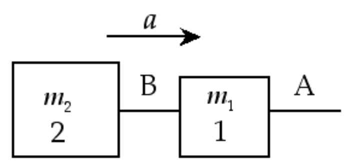
4.33 Taking the downward direction as positive, applying Newton's second law to the falling person yields $\Sigma F_y = mg - f = ma_y$, or

$$a_y = g - \frac{f}{m} = 9.80\ \text{m/s}^2 - \left(\frac{100\ \text{N}}{80\ \text{kg}}\right) = 8.6\ \text{m/s}^2$$

Then, $v_y^2 = v_{0y}^2 + 2\,a_y\ \ \Delta y$ gives the velocity just before hitting the net as

$$v_y = \sqrt{v_{0y}^2 + 2\,a_y\ \ \Delta y} = \sqrt{0 + 2\ \ 8.6\ \text{m/s}^2\ \ \ 30\ \text{m}} = \boxed{23\ \text{m/s}}$$

4.34 (a) First, consider a system consisting of the two blocks combined, with mass $m_1 + m_2$. For this system, the only external horizontal force is the tension in cord A pulling to the right. The tension in cord B is a force one part of our system exerts on another part of our system, and is therefore an internal force.



Applying Newton's second law to this system (including only external forces, as we should) gives

$$\Sigma F_x = ma \qquad \Rightarrow \qquad T_A = m_1 + m_2\ \ a$$

[1]

Now, consider a system consisting of only m_2. For this system, the tension in cord B is an external force since it is a force exerted on block 2 by block 1 (which is not part of this system). Applying Newton's second law to this system gives

$$\Sigma F_x = ma \qquad \Rightarrow \qquad T_B = m_2 a$$

[2]

Comparing equations [1] and [2], and realizing that the acceleration is the same in both cases (see Part (b) below), it is clear that:

$\boxed{\text{Cord A exerts a larger force on block 1 than cord B exerts on block 2}}$

(b) Since cord B connecting the two blocks is taut and unstretchable, the two blocks stay a fixed distance apart, and the velocities of the two blocks must be equal at all times. Thus, the rates at which the velocities of the two blocks change in time are equal, or the

$\boxed{\text{the two blocks must have equal accelerations}}$.

(c) Yes. Block 1 exerts a forward force on Cord B, so Newton's third law tells us that Cord B exerts a force of equal magnitude in the backward direction on Block 1.

4.35 (a) When the acceleration is upward, the total upward force $\boxed{T}$ must exceed the total downward force

$$w = mg = \left(1\,500 \text{ kg}\right)\left(9.80 \text{ m/s}^2\right) = 1.47 \times 10^4 \text{ N}$$

(b) When the velocity is constant, the acceleration is zero. The total upward force T and the total downward force w must be $\boxed{\text{equal in magnitude}}$.

(c) If the acceleration is directed downward, the total downward force $\boxed{w}$ must exceed the total upward force T.

(d) $\Sigma F_y = ma_y \quad \Rightarrow \quad T = mg + ma_y = \left(1\,500 \text{ kg}\right)\left(9.80 \text{ m/s}^2 + 2.50 \text{ m/s}^2\right) = \boxed{1.85 \times 10^4 \text{ N}}$

$\boxed{\text{Yes}}$, $T > w$.

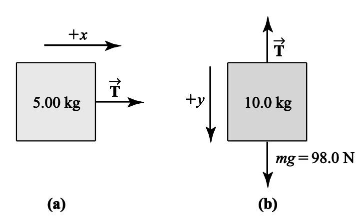
(e) $\Sigma F_y = ma_y \quad \Rightarrow \quad T = mg + ma_y = \left(1\,500 \text{ kg}\right)\left(9.80 \text{ m/s}^2 + 0\right) = \boxed{1.47 \times 10^4 \text{ N}}$

$\boxed{\text{Yes}}$, $T = w$.

(f) $\Sigma F_y = ma_y \quad \Rightarrow \quad T = mg + ma_y = \left(1\,500 \text{ kg}\right)\left(9.80 \text{ m/s}^2 - 1.50 \text{ m/s}^2\right) = \boxed{1.25 \times 10^4 \text{ N}}$

$\boxed{\text{Yes}}$, $T < w$.

4.36 Note that if the cord connecting the two blocks has a fixed length, the accelerations of the blocks must have equal magnitudes, even though they differ in directions. Also, observe from the diagrams, we choose the positive direction for each block to be in its direction of motion.



(First consider the block moving along the horizontal. The only force in the direction of movement is T. Thus,

$$\Sigma F_x = ma_x \quad \Rightarrow \quad T = \left(5.00 \text{ kg}\right)a \qquad [1]$$

Next consider the block which moves vertically. The forces on it are the tension T and its weight, 98.0 N. $\Sigma F_y = ma_y \Rightarrow$

$$98.0 \text{ N} - T = \left(10.0 \text{ kg}\right)a \qquad [2]$$

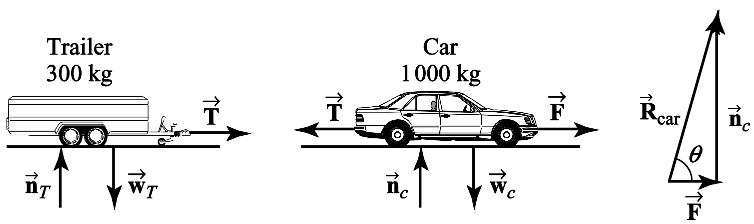
Equations [1] and [2] can be solved simultaneously to give:

$$98.0\text{ N} - (5.00\text{ kg})a = (10.0\text{ kg})a \qquad \text{or} \qquad a = \frac{98.0\text{ N}}{15.0\text{ kg}} = \boxed{6.53\ \text{m/s}^2}$$

and

$$T = (5.00\text{ kg})(6.53\ \text{m/s}^2) = \boxed{32.7\text{ N}}$$

4.37



Choose the $+x$ direction to be horizontal and forward with the $+y$ vertical and upward. The common acceleration of the car and trailer then has components of $a_x = +2.15\ \text{m/s}^2$ and $a_y = 0$.

(a) The net force on the car is horizontal and given by

$$(\Sigma F_x)_{car} = F - T = m_{car}a_x = (1000\text{ kg})(2.15\ \text{m/s}^2) = \boxed{2.15 \times 10^3\text{ N forward}}$$

(b) The net force on the trailer is also horizontal and given by

$$(\Sigma F_x)_{trailer} = +T = m_{trailer}a_x = (300\text{ kg})(2.15\ \text{m/s}^2) = \boxed{645\text{ N forward}}$$

(c) Consider the free-body diagrams of the car and trailer. The only horizontal force acting on the trailer is $T = 645\text{ N forward}$, and this is exerted on the trailer by the car. Newton's third law then states that the force the trailer exerts on the car is $\boxed{645\text{ N toward the rear}}$.

(d) The road exerts two forces on the car. These are F and n_c shown in the free-body diagram of the car. From part (a),

$$F = T + 2.15\times10^3\ \text{N} = 645\ \text{N} + 2.15\times10^3\ \text{N} = +2.80\times10^3\ \text{N}$$

Also, $\left(\Sigma F_y\right)_{car} = n_c - w_c = m_{car}a_y = 0$, so $n_c = w_c = m_{car}g = 9.80\times10^3\ \text{N}$

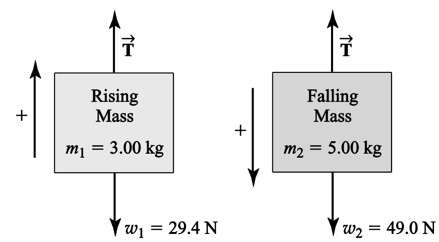
The resultant force exerted on the car by the road is then

$$R_{car} = \sqrt{F^2 + n_c^2} = \sqrt{\left(2.80\times10^3\ \text{N}\right)^2 + \left(9.80\times10^3\ \text{N}\right)^2} = 1.02\times10^4\ \text{N}$$

at $\theta = \tan^{-1}\left(\frac{n_c}{F}\right) = \tan^{-1}\left(3.51\right) = 74.1°$ above the horizontal and forward. Newton's third law then states that the resultant force exerted on the road by the car is

$\boxed{1.02\times10^4\ \text{N at } 74.1° \text{ below the horizontal and rearward}}$

4.38 First, consider the 3.00-kg rising mass. The forces on it are the tension, T, and its weight, 29.4 N. With the upward direction as positive, the second law becomes



$$T - 29.4\ \text{N} = \left(3.00\ \text{kg}\right)a \qquad [1]$$

The forces on the falling 5.00-kg mass are its weight and T, and its acceleration has the same magnitude as that of the rising mass. Choosing the positive direction down for this mass, gives

$$49.0\ \text{N} - T = \left(5.00\ \text{kg}\right)a \qquad [2]$$

(a) Solving Equation (2) for a and substituting into [1] gives

$$T - 29.4\ \text{N} = \left(\frac{3.00\ \text{kg}}{5.00\ \text{kg}}\right)\left(49.0\ \text{N} - T\right) \qquad \text{or} \qquad 1.60\,T = 58.8\ \text{N}$$

and the tension is $T = \boxed{36.8\ \text{N}}$

(b) Equation (2) then gives the acceleration as

$$a = \frac{49.0\ \text{N} - 36.8\ \text{N}}{5.00\ \text{kg}} = \boxed{2.44\ \text{m/s}^2}$$

(c) Consider the 3.00-kg mass. We have

$$\Delta y = v_{0y}t + \frac{1}{2}a_y t^2 = 0 + \frac{1}{2}\left(2.44\ \text{m/s}^2\right)\left(1.00\ \text{s}\right)^2 = \boxed{1.22\ \text{m}}$$

4.39 When the block is on the verge of moving, the static friction force has a magnitude $f_s = (f_s)_{\max} = \mu_s n$.

Since equilibrium still exists and the applied force is 75 N, we have

$$\Sigma F_x = 75\text{ N} - f_s = 0 \quad \text{or} \quad (f_s)_{\max} = 75\text{ N}$$

In this case, the normal force is just the weight of the crate, or $n = mg$. Thus, the coefficient of static friction is

$$\mu_s = \frac{(f_s)_{\max}}{n} = \frac{(f_s)_{\max}}{mg} = \frac{75\text{ N}}{(20\text{ kg})(9.80\text{ m/s}^2)} = \boxed{0.38}$$

After motion exists, the friction force is that of kinetic friction, $f_k = \mu_k n$.

Since the crate moves with constant velocity when the applied force is 60 N, we find that $\Sigma F_x = 60\text{ N} - f_k = 0$ or $f_k = 60\text{ N}$. Therefore, the coefficient of kinetic friction is

$$\mu_k = \frac{f_k}{n} = \frac{f_k}{mg} = \frac{60\text{ N}}{(20\text{ kg})(9.80\text{ m/s}^2)} = \boxed{0.31}$$

4.40 (a) The static friction force attempting to prevent motion may reach a maximum value of

$$(f_s)_{\max} = \mu_s n_1 = \mu_s m_1 g = (0.50)(10\text{ kg})(9.80\text{ m/s}^2) = 49\text{ N}$$

This exceeds the force attempting to move the system, $w_2 = m_2 g = 39\text{ N}$. Hence, the system remains at rest and the acceleration is $a = \boxed{0}$

(b) Once motion begins, the friction force retarding the motion is

$$f_k = \mu_k n_1 = \mu_k m_1 g = (0.30)(10\text{ kg})(9.80\text{ m/s}^2) = 29\text{ N}$$

This is less than the force trying to move the system, $w_2 = m_2 g$. Hence, the system gains speed at the rate

$$a = \frac{F_{net}}{m_{total}} = \frac{m_2 g - \mu_k m_1 g}{m_1 + m_2} = \frac{[4.0\text{ kg} - 0.30(10\text{ kg})](9.80\text{ m/s}^2)}{4.0\text{ kg} + 10\text{ kg}} = \boxed{0.70\text{ m/s}^2}$$

4.41 (a) Since the crate has constant velocity, $a_x = a_y = 0$.

Applying Newton's second law:

$$\Sigma F_x = F\cos 20.0° - f_k = ma_x = 0 \quad \text{or} \quad f_k = (300\text{ N})\cos 20.0° = 282\text{ N}$$

and

$$\Sigma F_y = n - F\sin 20.0° - w = 0 \qquad \text{or} \qquad n = (300\text{ N})\sin 20.0° + 1\,000\text{ N} = 1.10 \times 10^3\text{ N}$$

The coefficient of friction is then

$$\mu_k = \frac{f_k}{n} = \frac{282\text{ N}}{1.10 \times 10^3\text{ N}} = \boxed{0.256}$$

(b) In this case, $\Sigma F_y = n + F\sin 20.0° - w = 0$, so $n = w - F\sin 20.0° = 897\text{ N}$

The friction force now becomes $f_k = \mu_k n = (0.256)(897\text{ N}) = 230\text{ N}$

Therefore, $\Sigma F_x = F\cos 20.0° - f_k = ma_x = \left(\frac{w}{g}\right)a_x$ and the acceleration is

$$a = \frac{(F\cos 20.0° - f_k)g}{w} = \frac{\left[(300\text{ N})\cos 20.0° - 230\text{ N}\right](9.80\text{ m/s}^2)}{1\,000\text{ N}} = \boxed{0.509\text{ m/s}^2}$$

4.42 (a) $a_x = \dfrac{v_x - v_{0x}}{t} = \dfrac{6.00\text{ m/s} - 12.0\text{ m/s}}{5.00\text{ s}} = \boxed{-1.20\text{ m/s}^2}$

(b) From Newton's second law, $\Sigma F_x = -f_k = ma_x$, or $f_k = -ma_x$.

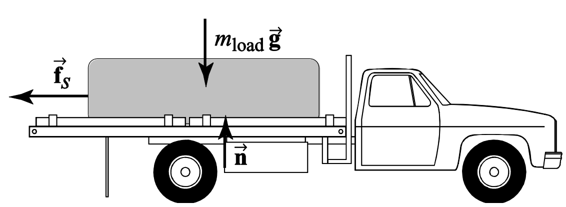
The normal force exerted on the puck by the ice is $n = mg$, so the coefficient of friction is

$$\mu_k = \frac{f_k}{n} = \frac{-m(-1.20\text{ m/s}^2)}{m(9.80\text{ m/s}^2)} = \boxed{0.122}$$

(c) $\Delta x = (v_x)_{av}t = \left(\dfrac{v_x + v_{0x}}{2}\right)t = \left(\dfrac{6.00\text{ m/s} + 12.0\text{ m/s}}{2}\right)(5.00\text{ s}) = \boxed{45.0\text{ m}}$

4.43 When the load on the verge of sliding forward on the bed of the slowing truck, the rearward directed static friction force has its maximum value

$$(f_s)_{max} = \mu_s n = \mu_s m_{load} g$$



Since slipping is not yet occurring, this single horizontal force must give the load an acceleration equal to that the truck.

Thus, $\Sigma F_x = ma_x \quad \Rightarrow \quad -\mu_s \cancel{m_{load}} g = \cancel{m_{load}} a_{truck} \qquad \text{or} \qquad a_{truck} = -\mu_s g$.

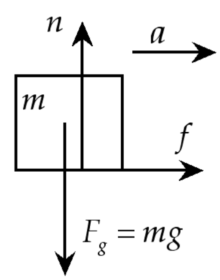
(a) If slipping is to be avoided, the maximum allowable rearward acceleration of the truck is seen to be $a_{truck} = -\mu_s g$, and $v_x^2 = v_{0x}^2 + 2a_x \ \Delta x$ gives the minimum stopping distance as

$$\Delta x_{\min} = \frac{0 - v_{0x}^2}{2 \ a_{truck \ \max}} = \frac{v_{0x}^2}{2\mu_s g}$$

If $v_{0x} = 12 \text{ m/s}$ and $\mu_s = 0.500$, then $\Delta x_{\min} = \dfrac{12.0 \text{ m/s}^{\ 2}}{2 \ 0.500 \quad 9.80 \text{ m/s}^2} = \boxed{14.7 \text{ m}}$

(b) Examining the calculation of Part (a) shows that $\boxed{\text{neither mass is necessary}}$

4.44 (a) The free-body diagram of the crate is shown at the right. Since the crate has no vertical acceleration $a_y = 0$, we see that



$$\Sigma F_y = ma_y \qquad \Rightarrow \qquad n - mg = 0 \qquad \text{or} \qquad n = mg$$

The only horizontal force present is the friction force exerted on the crate by the truck bed. Thus,

$$\Sigma F_x = ma_x \qquad \Rightarrow \qquad f = ma$$

If the crate is not to slip (i.e., the static case is to prevail), it is necessary that the required friction force not exceed the maximum possible static friction force, $f_{s \ \max} = \mu_s n$. From this, we find the maximum allowable acceleration as:

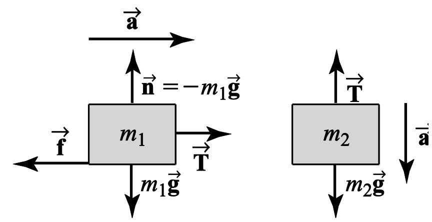
$$a_{\max} = \frac{f_{\max}}{m} = \frac{f_{s \ \max}}{m} = \frac{\mu_s n}{m} = \frac{\mu_s \ mg}{m} = \mu_s g = \ 0.350 \quad 9.80 \text{ m/s}^2 \ = \boxed{3.43 \text{ m/s}^2}$$

(b) Once slipping has started, the kinetic friction case prevails and $f = f_k = \mu_k n$. The acceleration of the crate in this case will be

$$a = \frac{f}{m} = \frac{\mu_k n}{m} = \frac{\mu_k \ mg}{m} = \mu_k g = \ 0.320 \quad 9.80 \text{ m/s}^2 \ = \boxed{3.14 \text{ m/s}^2}$$

4.45 (a) The acceleration of the system is found from

$$\Delta y = v_{0y}t + \frac{1}{2}at^2, \text{ or } 1.00 \text{ m} = 0 + \frac{1}{2}a \;\; 1.20 \text{ s}^{\;2}$$



which gives $a = 1.39 \text{ m/s}^2$

Using the free body diagram of m_2, the second law gives

$$5.00 \text{ kg} \;\; 9.80 \text{ m/s}^2 \;\; - T = \;\; 5.00 \text{ kg} \;\; 1.39 \text{ m/s}^2 \;\; \text{or}$$

$$T = 42.1 \text{ N}$$

Then applying the second law to the horizontal motion of m_1

$$42.1 \text{ N} - f = \;\; 10.0 \text{ kg} \;\; 1.39 \text{ m/s}^2 \;\; \text{or } f = 28.2 \text{ N}$$

Since $n = m_1 g = 98.0 \text{ N}$, we have

$$\mu_k = \frac{f}{n} = \frac{28.2 \text{ N}}{98.0 \text{ N}} = \boxed{0.287}$$

4.46 (a) Since the puck is on a horizontal surface, the normal force is vertical.

With $a_y = 0$, we see that

$$\Sigma F_y = ma_y \qquad \Rightarrow \qquad n - mg = 0 \qquad \text{or} \qquad n = mg$$

Once the puck leaves the stick, the only horizontal force is a friction force in the negative *x*-direction (to oppose the motion of the puck). The acceleration of the puck is

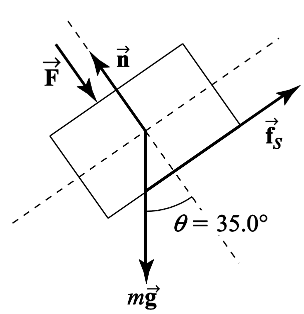
$$a_x = \frac{\Sigma F_x}{m} = \frac{-f_k}{m} = \frac{-\mu_k n}{m} = \frac{-\mu_k \;\; mg}{m} = \boxed{-\mu_k g}$$

(b) Then $v_x^2 = v_{0x}^2 + 2a_x \;\; \Delta x$ gives the horizontal displacement of the puck before coming to rest as

$$\Delta x = \frac{v_x^2 - v_{0x}^2}{2a_x} = \frac{0 - v_0^2}{2 \;\; -\mu_k g} = \boxed{\frac{v_0^2}{2\mu_k g}}$$

4.47 (a) The crate does not accelerate perpendicular to the incline. Thus,

$$\Sigma F_\perp = ma_\perp = 0 \quad \Rightarrow \quad n = F + mg\cos\theta$$



The net force tending to move the crate down the incline is

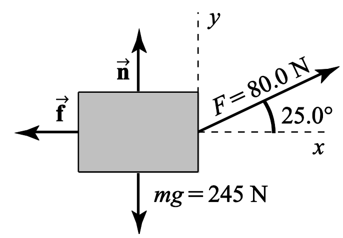
$\Sigma F_{\parallel} = mg\sin\theta - f_s$, where f_s is the force of static friction between the crate and the incline. If the crate is in equilibrium, then $mg\sin\theta - f_s = 0$ so $f_s = F_g \sin\theta$

But, we also know $f_s \leq \mu_s n = \mu_s \;\; F + mg\cos\theta$

Therefore, we may write $\quad mg\sin\theta \leq \mu_s \;\; F + mg\cos\theta$ or,

$$F \geq mg\left(\frac{\sin\theta}{\mu_s} - \cos\theta\right) = \;3.00\text{ kg}\;\;\; 9.80\text{ m/s}^2\;\left(\frac{\sin 35.0°}{0.300} - \cos 35.0°\right) = \boxed{32.1\text{ N}}$$

4.48 (a) Find the normal force $\vec{\mathbf{n}}$ on the 25.0 kg box:



$$\Sigma F_y = n + \;80.0\text{ N}\;\;\sin 25.0° - 245\text{ N} = 0$$

or $n = 211$ N

Now find the friction force, *f*, as

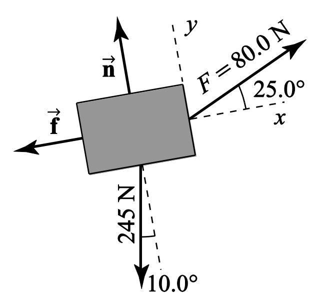
$$f = \mu_k n = \;0.300\;\; 211\text{ N}\;\; = 63.4\text{ N}$$

From the second law, we have $\Sigma F_x = ma$, or

$$80.0\text{ N}\;\;\cos 25.0° - 63.4\text{ N} = \;25.0\text{ kg}\;\; a$$

which yields $a = \boxed{0.366\text{ m/s}^2}$.

(b) When the box is on the incline,



$$\Sigma F_y = n + \;\;80.0\text{ N}\;\;\sin 25.0° - \;\;245\text{ N}\;\;\cos 10.0° = 0$$

giving $n = 207$ N

The friction force is $f = \mu_k n = \;0.300\;\; 207\text{ N}\;\; = 62.2\text{ N}$

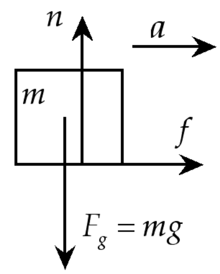
The net force parallel to the incline is then

$$\Sigma F_x = \;\;80.0\text{ N}\;\;\cos 25.0° - \;\;245\text{ N}\;\;\sin 10.0° - 62.2\text{ N} = -32.3\text{ N}$$

Thus,

$$a = \frac{\Sigma F_x}{m} = \frac{-32.3\text{ N}}{25.0\text{ kg}} = -1.29\text{ m/s}^2 \text{ or } \boxed{1.29\text{ m/s}^2\text{ down the incline}}$$

4.49 (a) The object will fall so that $ma = mg - bv$, or $a = \dfrac{mg - bv}{m}$



where the downward direction is taken as positive.

Equilibrium $a = 0$ is reached when

$$v = v_{terminal} = \frac{mg}{b} = \frac{50 \text{ kg} \quad 9.80 \text{ m/s}^2}{15 \text{ kg/s}} = \boxed{33 \text{ m/s}}$$

(b) If the initial velocity is less than 33 m/s, then $a \geq 0$ and 33 m/s is the largest velocity attained by the object. On the other hand, if the initial velocity is *greater* than 33 m/s, then $a \leq 0$ and 33 m/s is the *smallest* velocity attained by the object. Note also that if the initial velocity is 33 m/s, then $a = 0$ and the object continues falling with a constant speed of 33 m/s.

4.50 (a) The force of friction is found as $f = \mu_k n = \mu_k \quad mg$

Choose the positive direction of the x-axis in the direction of motion and apply Newton's second law. We have

$$\Sigma F_x = -f = ma_x \qquad \text{or} \qquad a_x = \frac{-f}{m} = -\mu_k g$$

From $v^2 = v_0^2 + 2a \quad \Delta x$, with $v = 0$, $v_0 = 50.0 \text{ km/h} = 13.9 \text{ m/s}$, we find

$$0 = \quad 13.9 \text{ m/s} \quad ^2 + 2 \quad -\mu_k g \quad \Delta x \qquad \text{or} \qquad \Delta x = \frac{\quad 13.9 \text{ m/s} \quad ^2}{2\mu_k g} \qquad [1]$$

With $\mu_k = 0.100$, this gives

$$\Delta x = \frac{\quad 13.9 \text{ m/s} \quad ^2}{2 \quad 0.100 \quad 9.80 \text{ m/s}^2} = \boxed{98.6 \text{ m}}$$

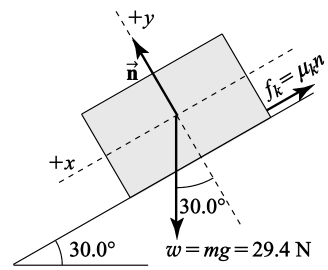
(b) With $\mu_k = 0.600$, Equation (1) above gives

$$\Delta x = \frac{\quad 13.9 \text{ m/s} \quad ^2}{2 \quad 0.600 \quad 9.80 \text{ m/s}^2} = \boxed{16.4 \text{ m}}$$

4.51 (a) $\Delta x = v_0 t + \frac{1}{2} a_x t^2 = 0 + \frac{1}{2} a_x t^2$ gives:

$$a_x = \frac{2 \ \Delta x}{t^2} = \frac{2 \ 2.00 \text{ m}}{1.50 \text{ s} \ ^2} = \boxed{1.78 \text{ m/s}^2}$$

(b) Considering forces parallel to the incline, Newton's second law yields



$$\Sigma F_x = 29.4 \text{ N} \ \sin 30.0° - f_k = 3.00 \text{ kg} \ \ 1.78 \text{ m/s}^2$$

or $f_k = 9.37$ N

Perpendicular to the plane, we have equilibrium, so

$$\Sigma F_y = n - 29.4 \text{ N} \ \cos 30.0° = 0 \qquad \text{or} \qquad n = 25.5 \text{ N}$$

Then,

$$\mu_k = \frac{f_k}{n} = \frac{9.37 \text{ N}}{25.5 \text{ N}} = \boxed{0.368}$$

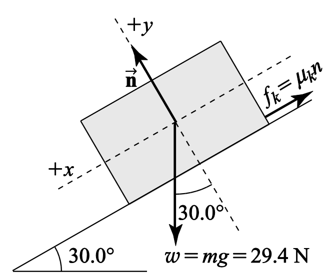
(c) From part (b) above, $f_k = \boxed{9.37 \text{ N}}$

(d) Finally, $v^2 = v_0^2 + 2a_x \ \Delta x$ gives

$$v = \sqrt{v_0^2 + 2a_x \ \ \Delta x} = \sqrt{0 + 2 \ 1.78 \text{ m/s}^2 \ \ 2.00 \text{ m}} = \boxed{2.67 \text{ m/s}}$$

4.52 (b) When the minimum force $\vec{\mathbf{F}}$ is used, the block tends to slide down the incline so the friction force, $\vec{\mathbf{f}}_s$ is directed up the incline.

While the block is in equilibrium, we have



$$\Sigma F_x = F \cos 60.0° + f_s - 19.6 \text{ N} \ \sin 60.0° = 0$$

[1]

and

$$\Sigma F_y = n - F \sin 60.0° - 19.6 \text{ N} \ \cos 60.0° = 0 \qquad [2]$$

For minimum F (impending motion), $f_s = f_{s\,\max} = \mu_s n = 0.300\ n$

[3]

Equation [2] gives $n = 0.866F + 9.80\ \text{N}$

[4]

(a) Equation [3] becomes: $f_s = 0.300\ \ 0.866F + 9.80\ \text{N}\ \ = 0.260\,F + 2.94\ \text{N}$, so

Equation [1] gives $0.500F + 0.260F + 2.94\ \text{N} - 17.0\ \text{N} = 0$ or $F = \boxed{18.5\ \text{N}}$.

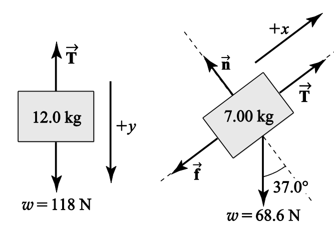
(b) Finally, Equation (4) gives the normal force $n = 0.866\ \ 18.5\ \text{N}\ \ + 9.80\ \text{N} = \boxed{25.8\ \text{N}}$.

4.53 b) First, taking downward as positive, apply Newton's second law to the 12.0 kg block:

$$\Sigma F_y = 12.0\ \text{kg}\ \ g - T = 12.0\ \text{kg}\ \ a$$

or

$$T = 12.0\ \text{kg}\ \ \ 9.80\ \text{m/s}^2 - a \qquad [1]$$



For the 7.00 kg block, we have

$$\Sigma F_\perp = 0 \quad \Rightarrow \quad n = 68.6\ \text{N}\ \ \cos 37.0° = 54.8\ \text{N}$$

and

$$f = \mu_k n = 0.250\ \ \ 54.8\ \text{N}\ \ = 13.7\ \text{N}$$

Taking up the incline as the positive direction and applying Newton's second law to the 7.00-kg block gives $\Sigma F_x = T - f - \ 68.6\ \text{N}\ \sin 37.0° = 7.00\ \text{kg}\ \ a$, or

$$7.00\ \text{kg}\ \ a = T - 13.7\ \text{N} - 41.3\ \text{N} \qquad (2)$$

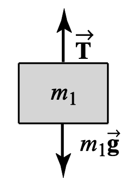
Substituting Equation [1] into [2] yields

$$7.00\ \text{kg} + 12.0\ \text{kg}\ \ a = 62.7\ \text{N} \ \text{ or } a = \boxed{3.30\ \ \text{m/s}^2}$$

4.54 (a) Both objects start from rest and have accelerations of the same magnitude, a. This magnitude can be determined by applying $\Delta y = v_{0y}t + \frac{1}{2}a_y t^2$ to the motion of m_1 :

$$a = \frac{2\ \Delta y}{t^2} = \frac{2\ 1.00\ \text{m}}{4.00\text{s}\ ^2} = \boxed{0.125\ \text{m/s}^2}$$

(b) Consider the free-body diagram of m_1 and apply Newton's 2nd law:

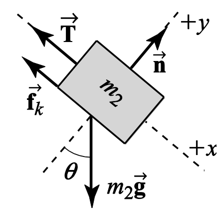


$$\Sigma F_y = ma_y \quad \Rightarrow \quad T - m_1 g = m_1\ +a$$

or

$$T = m_1\ g + a\ = \ 4.00\ \text{kg}\ \ 9.80\ \text{m/s}^2 + 0.125\ \text{m/s}^2\ = \boxed{39.7\ \text{N}}$$

(c) Considering the free-body diagram of m_2 :



$$\Sigma F_y = ma_y \quad \Rightarrow \quad n - m_2 g\cos\theta = 0 \ \text{ or } \ n = m_2 g\cos\theta,$$

so $\quad n = \ 9.00\ \text{kg}\ \ 9.80\ \text{m/s}^2\ \cos 40.0° = 67.6\ \text{N}$.

$$\Sigma F_x = ma_x \quad \Rightarrow \quad m_2 g\sin\theta - T - f_k = m_2\ +a$$

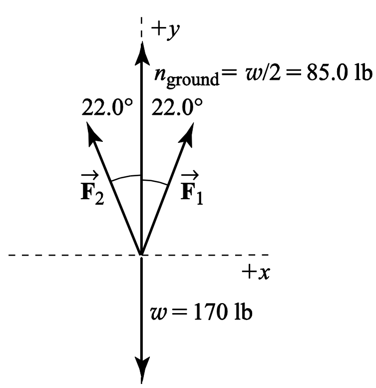
Then $f_k = m_2\ g\sin\theta - a\ - T$, or

$$f_k = \ 9.00\ \text{kg}\left[\ 9.80\ \text{m/s}^2\ \sin 40.0° - 0.125\ \text{m/s}^2\right] - 39.7\ \text{N} = 15.9\ \text{N}$$

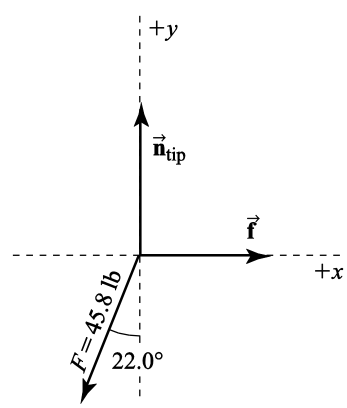
The coefficient of kinetic friction is

$$\mu_k = \frac{f_k}{n} = \frac{15.9\ \text{N}}{67.6\ \text{N}} = \boxed{0.235}$$

4.55



Free-Body Diagram of Person



Free-Body Diagram of Crutch Tip

From the free-body diagram of the person, $\Sigma F_x = F_1 \sin 22.0° - F_2 \sin 22.0° = 0$, which gives

or $F_1 = F_2 = F$

Then, $\Sigma F_y = 2F \cos 22.0° + 85.0 \text{ lbs} - 170 \text{ lbs} = 0$ yields $F = 45.8 \text{ lb}$

(a) Now consider the free-body diagram of a crutch tip.

$$\Sigma F_x = f - 45.8 \text{ lb} \sin 22.0° = 0,$$

or

$$f = 17.2 \text{ lb}$$

$$\Sigma F_y = n_{tip} - 45.8 \text{ lb} \cos 22.0° = 0,$$

which gives $n_{tip} = 42.5 \text{ lb}$

For minimum coefficient of friction, the crutch tip will be on the verge of slipping, so

$f = f_{s\ \max} = \mu_s n_{tip}$

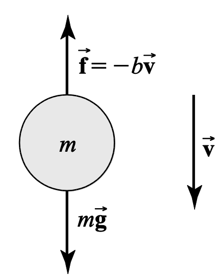
and $\mu_s = \dfrac{f}{n_{tip}} = \dfrac{17.2 \text{ lb}}{42.5 \text{ lb}} = \boxed{0.404}$

(b) As found above, the compression force in each crutch is

$F_1 = F_2 = F = \boxed{45.8 \text{ lb}}$

4.56 (b) The acceleration of the ball is found from

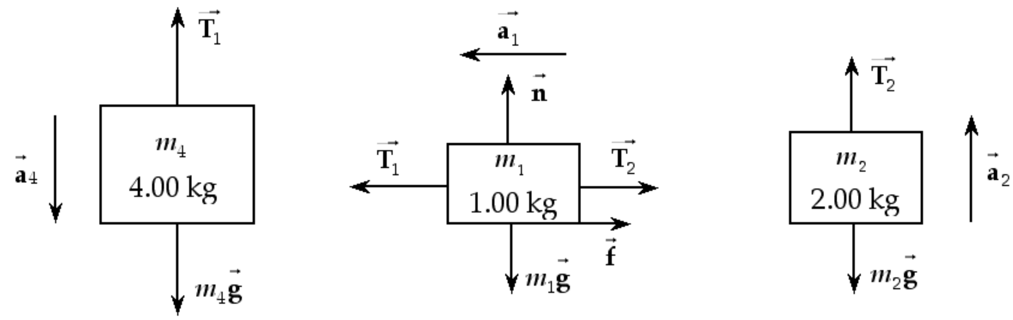
$$a = \frac{v^2 - v_0^2}{2\ \Delta y} = \frac{20.0 \text{ m/s}^{\ 2} - 0}{2\ 1.50 \text{ m}} = 133 \text{ m/s}^2$$



From the second law, $\Sigma F_y = F - w = ma_y$, so

$$F = w + ma_y = 1.47 \text{ N} + 0.150 \text{ kg} \quad 133 \text{ m/s}^2 = \boxed{21.5 \text{ N}}$$

4.57 (a)



(b) Note that the suspended block on the left, m_4, is heavier than that on the right, m_2. Thus, if the system overcomes friction and moves, the center block will move right to left with each block's acceleration being $\boxed{\text{in the directions shown above}}$.

First, consider the center block, m_1, which has no vertical acceleration. Then,

$$\Sigma F_y = n - m_1 g = 0 \qquad \text{or} \qquad n = m_1 g = \ 1.00\text{ kg} \quad 9.80\ \text{m/s}^2 \ = 9.80\text{ N}$$

This means the friction force is:

$$f = \mu_k n = \ 0.350 \quad 9.80\text{ N} \ = 3.43\text{ N}$$

Assuming the cords do not stretch, the speeds of the three blocks must always be equal. Thus, the magnitudes of the blocks' accelerations must have a common value, a.

$$\left|\vec{\mathbf{a}}_4\right| = \left|\vec{\mathbf{a}}_1\right| = \left|\vec{\mathbf{a}}_2\right| = a$$

Taking the indicated direction of the acceleration as the positive direction of motion for each block, we apply Newton's second law to each block as follows

For m_4:	$m_4 g - T_1 = m_4 a$	or	$T_1 = m_4 \ g - a \ = \ 4.00\text{ kg} \quad g - a$	[1]
For m_1:	$T_1 - T_2 - f = m_1 a$	or	$T_1 - T_2 = \ 1.00\text{ kg} \ a + 3.43\text{ N}$	[2]
For m_2:	$T_2 - m_2 g = m_2 a$	or	$T_2 = m_2 \ g + a \ = \ 2.00\text{ kg} \quad g + a$	[3]

Substituting equations [1] and [3] into equation [2], and solving for a yields the following:

$$4.00\text{ kg} \quad g - a \ - \ 2.00\text{ kg} \quad g + a \ = \ 1.00\text{ kg} \ a + 3.43\text{ N}$$

$$a = \frac{4.00\text{ kg} - 2.00\text{ kg} \quad 9.80\ \text{m/s}^2 \ - 3.43\text{ N}}{4.00\text{ kg} + 2.00\text{ kg} + 1.00\text{ kg}} = \boxed{2.31\ \text{m/s}^2}$$

(c) Using this result in equations [1] and [3] gives the tensions in the two cords as:

$$T_1 = (4.00 \text{ kg})(g - a) = (4.00 \text{ kg})(9.80 - 2.31) \text{ m/s}^2 = \boxed{30.0 \text{ N}}$$

and

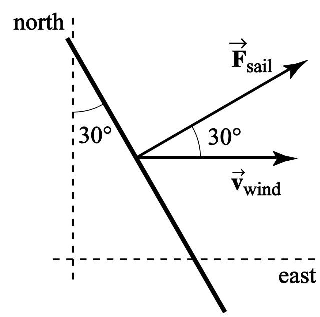
$$T_2 = (2.00 \text{ kg})(g + a) = (2.00 \text{ kg})(9.80 + 2.31) \text{ m/s}^2 = \boxed{24.2 \text{ N}}$$

(e) From the final calculation in part (b), observe that if the friction force had a value of zero (rather than 3.53 N), the acceleration of the system would increase in magnitude. Then, observe from equations [1] and [3] that this would mean $\boxed{T_1 \text{ would decrease}}$ while $\boxed{T_2 \text{ would increase}}$

4.58 The sketch at the right gives an edge view of the sail (heavy line) as seen from above. The velocity of the wind, $\vec{\mathbf{v}}_{wind}$, is directed to the east and the force the wind exerts on the sail is perpendicular to the sail. The magnitude of this force is

$$F_{sail} = \left(550 \ \frac{\text{N}}{\text{m/s}}\right)\left|\vec{\mathbf{v}}_{wind}\right|_{\perp}$$

where $\left|\vec{\mathbf{v}}_{wind}\right|_{\perp}$ is the component of the wind velocity perpendicular to the sail.



When the sail is oriented at 30° from the north-south line and the wind speed is $v_{wind} = 17$ knots, we have

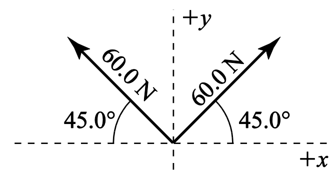
$$F_{sail} = \left(550 \ \frac{\text{N}}{\text{m/s}}\right)\left|\vec{\mathbf{v}}_{wind}\right|_{\perp} = \left(550 \ \frac{\text{N}}{\text{m/s}}\right)\left[(17 \cancel{\text{ knots}})\left(\frac{0.514 \text{ m/s}}{1 \cancel{\text{ knot}}}\right)\cos 30°\right] = 4.2 \times 10^3 \text{ N}$$

The eastward component of this force will be counterbalanced by the force of the water on the keel of the boat. Before the sailboat has significant speed (that is, before the drag force develops), its acceleration is provided by the northward component of $\vec{\mathbf{F}}_{sail}$. Thus, the initial acceleration is

$$a = \frac{\left|\vec{\mathbf{F}}_{sail}\right|_{north}}{m} = \frac{(4.2 \times 10^3 \text{ N})\sin 30°}{800 \text{ kg}} = \boxed{2.6 \text{ m/s}^2}$$

4.59 (a) The horizontal component of the resultant force exerted on the light by the cables is

$$R_x = \Sigma F_x = (60.0 \text{ N})\cos 45.0° - (60.0 \text{ N})\cos 45.0° = 0$$



The resultant y component is:

$$R_y = \Sigma F_y = (60.0 \text{ N})\sin 45.0° + (60.0 \text{ N})\sin 45.0° = 84.9 \text{ N}$$

Hence, the resultant force is $\boxed{84.9 \text{ N vertically upward}}$.

(b) The forces on the traffic light are the weight, directed downward, and the 84.9 N vertically upward force exerted by the cables. Since the light is in equilibrium, the resultant of these forces must be zero. Thus, $w = \boxed{84.9 \text{ N}}$.

4.60 (a) For the suspended block, $\Sigma F_y = T - 50.0 \text{ N} = 0$, so the tension in the rope is $T = 50.0 \text{ N}$. Then, considering the horizontal forces on the 100-N block, we find

$$\Sigma F_x = T - f_s = 0 \text{, or } f_s = T = \boxed{50.0 \text{ N}}$$

(b) If the system is on the verge of slipping, $f_s = (f_s)_{\text{max}} = \mu_s n$. Therefore, the minimum acceptable coefficient of friction is

$$\mu_s = \frac{f_s}{n} = \frac{50.0 \text{ N}}{100 \text{ N}} = \boxed{0.500}$$

(c) If $\mu_k = 0.250$, then the friction force acting on the 100-N block is

$$f_k = \mu_k n = (0.250)(100 \text{ N}) = 25.0 \text{ N}$$

Since the system is to move with constant velocity, the net horizontal force on the 100-N block must be zero, or $\Sigma F_x = T - f_k = T - 25.0 \text{ N} = 0$. The required tension in the rope is $T = 25.0 \text{ N}$. Now, considering the forces acting on the suspended block when it moves with constant velocity, $\Sigma F_y = T - w = 0$, giving the required weight of this block as $w = T = \boxed{25.0 \text{ N}}$.

4.61 On the level surface, the normal force exerted on the sled by the ice equals the total weight, or $n = 600$ N. Thus, the friction force is

$$f = \mu_k n = (0.050)(600\ \text{N}) = 30\ \text{N}$$

Hence, Newton's second law yields $\Sigma F_x = -f = ma_x$, or

$$a_x = \frac{-f}{m} = \frac{-f}{w/g} = \frac{-(30\ \text{N})(9.80\ \text{m/s}^2)}{600\ \text{N}} = -0.49\ \text{m/s}^2$$

The distance the sled travels on the level surface before coming to rest is

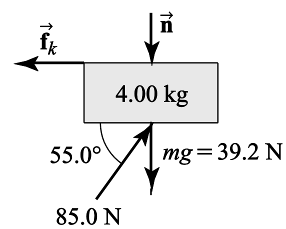
$$\Delta x = \frac{v_x^2 - v_{0x}^2}{2a_x} = \frac{0 - (7.0\ \text{m/s})^2}{2(-0.49\ \text{m/s}^2)} = \boxed{50\ \text{m}}$$

4.62 Consider the vertical forces acting on the block:

$$\Sigma F_y = (85.0\ \text{N})\sin 55.0° - 39.2\ \text{N} - n = ma_y = 0,$$

so the normal force is $\quad n = 69.6\ \text{N} - 39.2\ \text{N} = 30.4\ \text{N}$

Now, consider the horizontal forces:



$$\Sigma F_x = (85.0\ \text{N})\cos 55.0° - f_k = ma_x = (4.00\ \text{kg})(6.00\ \text{m/s}^2)$$

or

$$f_k = (85.0\ \text{N})\cos 55.0° - 24.0\ \text{N} = 24.8\ \text{N}$$

The coefficient of kinetic friction is then $\mu_k = \dfrac{f_k}{n} = \dfrac{24.8\ \text{N}}{30.4\ \text{N}} = \boxed{0.814}$.

4.63 (a) The force that accelerates the box is $\boxed{\text{the friction force}}$ between the box and the truck bed.

(b) The maximum acceleration the truck can have before the box slides is found by considering the maximum static friction force the truck bed can exert on the box:

$$(f_s)_{\text{max}} = \mu_s n = \mu_s(mg)$$

Thus, from Newton's second law,

$$a_{\text{max}} = \frac{(f_s)_{\text{max}}}{m} = \frac{\mu_s(mg)}{m} = \mu_s g = (0.300)(9.80\ \text{m/s}^2) = \boxed{2.94\ \text{m/s}^2}$$

4.64 Let $m_1 = 5.00$ kg, $m_2 = 4.00$ kg, and $m_3 = 3.00$ kg. Let T_1 be the tension in the string between m_1 and m_2, and T_2 the tension in the string between m_2 and m_3.

(a) We may apply Newton's second law to each of the masses.

for $m1$: $m_1 a = T_1 - m_1 g$ [1] for m_2 :

Adding these equations yields $m_1 + m_2 + m_3 \; a = -m_1 + m_2 + m_3 \; g$, so $a = \left(\dfrac{-m_1 + m_2 + m_3}{m_1 + m_2 + m_3} \right) g = \left(\dfrac{2.00 \text{ kg}}{12.0 \text{ kg}} \right)$

(b) From Equation [1], $T_1 = m_1 \; a + g = 5.00 \text{ kg} \;\; 11.4 \text{ m/s}^2 = \boxed{57.2 \text{ N}}$, and

from Equation [3], $T_2 = m_3 \; g - a = 3.00 \text{ kg} \;\; 8.17 \text{ m/s}^2 = \boxed{24.5 \text{ N}}$

4.65 When an object of mass m is on this frictionless incline, the only force acting parallel to the incline is the parallel component of weight, $mg \sin\theta$ directed down the incline. The acceleration is then

$$a = \frac{F_{\parallel}}{m} = \frac{mg\sin\theta}{m} = g\sin\theta = 9.80 \text{ m/s}^2 \;\; \sin 35.0° = 5.62 \text{ m/s}^2 \text{ (directed down the incline)}$$

(a) Taking up the incline as positive, the time for the sled projected up the incline to come to rest is given by $t = \dfrac{v - v_0}{a} = \dfrac{0 - 5.00 \text{ m/s}}{-5.62 \text{ m/s}^2} = 0.890 \text{ s}$

The distance the sled travels up the incline in this time is

$$\Delta s = v_{\text{av}}\, t = \left(\frac{v + v_0}{2} \right) t = \left(\frac{0 + 5.00 \text{ m/s}}{2} \right) \; 0.890 \text{ s} = \boxed{2.22 \text{ m}}$$

(b) The time required for the first sled to return to the bottom of the incline is the same as the time needed to go up, that is, $t = 0.890$ s. In this time, the second sled must travel down the entire 10.0 m length of the incline. The needed initial velocity is found from $\Delta s = v_0 t + \dfrac{1}{2} a t^2$ as

$$v_0 = \frac{\Delta s}{t} - \frac{at}{2} = \frac{-10.0 \text{ m}}{0.890 \text{ s}} - \frac{-5.62 \text{ m/s}^2 \;\; 0.890 \text{ s}}{2} = -8.74 \text{ m/s}$$

or $\boxed{8.74 \text{ m/s down the incline}}$.

4.66 Before she enters the water, the diver is in free-fall with an acceleration of $9.80\ \text{m/s}^2$ downward. Taking downward as the positive direction, her velocity when she reaches the water is given by

$$v = \sqrt{v_0^2 + 2a\ \ \Delta y} = \sqrt{0 + 2\ \ 9.80\ \text{m/s}^2\ \ \ 10.0\ \text{m}} = 14.0\ \text{m/s}$$

This is also her initial velocity for the 2.00 s after hitting the water. Her average acceleration during this 2.00 s interval is

$$a_{\text{av}} = \frac{v - v_0}{t} = \frac{0 -\ \ 14.0\ \text{m/s}}{2.00\ \text{s}} = -7.00\ \text{m/s}^2$$

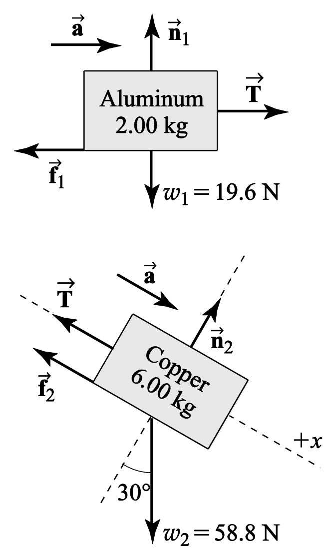
Continuing to take downward as the positive direction, the average upward force by the water is found as $\Sigma F_y = F_{\text{av}} + mg = ma_{\text{av}}$, or

$$F_{\text{av}} = m\ \ a_{\text{av}} - g\ \ = \ \ 70.0\ \text{kg}\left[\ -7.00\ \text{m/s}^2\ \ -9.80\ \text{m/s}^2\right] = -1.18\times 10^3\ \text{N}$$

or

$$F_{\text{av}} = \boxed{1.18\times 10^3\ \text{N}\ \ \text{upward}}$$

4.67 (a) Free-body diagrams for the two blocks are given at the right. The coefficient of kinetic friction for aluminum on steel is $\mu_1 = 0.47$ while that for copper on steel is $\mu_2 = 0.36$. Since $a_y = 0$ for each block,



$$n_1 = w_1 \text{ and } n_2 = w_2 \cos 30.0°.$$

Thus,

$$f_1 = \mu_1 n_1 = 0.47\ \ 19.6\ \text{N}\ \ = 9.21\ \text{N}$$

and

$$f_2 = \mu_2 n_2 = 0.36\ \ 58.8\ \text{N}\ \ \cos 30.0° = 18.3\ \text{N}$$

For the aluminum block:

$$\Sigma F_x = ma_x \quad\Rightarrow\quad T - f_1 = m\ \ +a \quad \text{or}\quad T = f_1 + ma$$

giving $\qquad T = 9.21\ \text{N} +\ \ 2.00\ \text{kg}\ \ a \qquad [1]$

For the copper block:

$$\Sigma F_x = ma_x \quad\Rightarrow\quad 58.8\ \text{N}\ \ \sin 30.0° - T - 18.3\ \text{N} = \ \ 6.00\ \text{kg}\ \ a$$

or $\qquad 11.1\ \text{N} - T = \ \ 6.00\ \text{kg}\ \ a \qquad [2]$

Substituting Equation [1] into Equation [2] gives

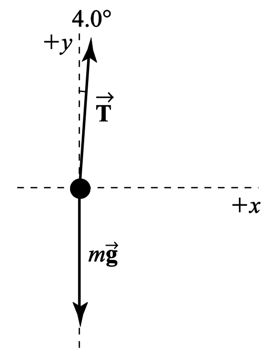
$$11.1\ \text{N} - 9.21\ \text{N} -\ \ 2.00\ \text{kg}\ \ a = \ \ 6.00\ \text{kg}\ \ a$$

or

$$a = \frac{1.86\ \text{N}}{8.00\ \text{kg}} = \boxed{0.232\ \text{m/s}^2}$$

(b) From Equation [1] above, $T = 9.21\ \text{N} + \ 2.00\ \text{kg} \quad 0.232\ \text{m/s}^2 \ = \boxed{9.68\ \text{N}}$.

4.68 In the vertical direction, we have



$$\Sigma F_y = T\cos 4.0° - mg = 0\text{, or } T = \frac{mg}{\cos 4.0°}$$

In the horizontal direction, the second law becomes:

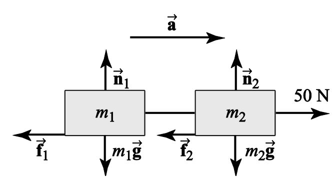
$$\Sigma F_x = T\sin 4.0° = ma\text{, so}$$

$$a = \frac{T\sin 4.0°}{m} = g\tan 4.0° = \boxed{0.69\ \text{m/s}^2}$$

4.69 Figure 1 is a free-body diagram for the system consisting of both blocks. The friction forces are

$$f_1 = \mu_k n_1 = \mu_k \ m_1 g \quad \text{and} \quad f_2 = \mu_k \ m_2 g$$

For this system, the tension in the connecting rope is an internal force and is not included in second law calculations. The second law gives



$$\Sigma F_x = 50\ \text{N} - f_1 - f_2 = \ m_1 + m_2 \ a$$

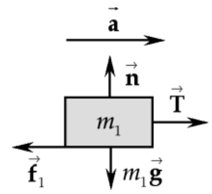
which reduces to

$$a = \frac{50\ \text{N}}{m_1 + m_2} - \mu_k g \qquad [1]$$

Figure 2 gives a free-body diagram of m_1 alone. For this system, the tension is an external force and must be included in the second law. We find: $\Sigma F_x = T - f_1 = m_1 a$, or

$$T = m_1 \ a + \mu_k g \qquad [2]$$

If the surface is frictionless, $\mu_k = 0$. Then, Equation [1] gives



$$a = \frac{50\ \text{N}}{m_1 + m_2} - 0 = \frac{50\ \text{N}}{30\ \text{kg}} = \boxed{1.7\ \text{m/s}^2}$$

and Equation [2] yields $T = 10\text{ kg}\quad 1.7\text{ m/s}^2 + 0 = \boxed{17\text{ N}}$.

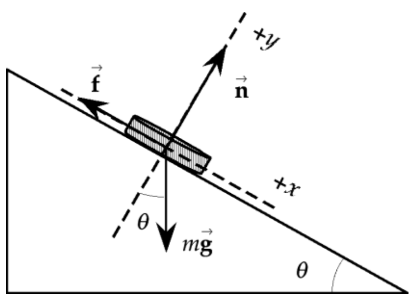
(b) If $\mu_k = 0.10$, Equation [1] gives the acceleration as

$$a = \frac{50\text{ N}}{30\text{ kg}} - 0.10\quad 9.80\text{ m/s}^2 = \boxed{0.69\text{ m/s}^2}$$

while Equation (2) gives the tension as

$$T = 10\text{ kg}\left[0.69\text{ m/s}^2 + 0.10\quad 9.80\text{ m/s}^2\right] = \boxed{17\text{ N}}$$

4.70 (a)



(b) $\boxed{\text{No.}}$ In general, the static friction force is less than the maximum value of $f_{s\,\max} = \mu_s n$. It is equal to this maximum value only when the coin is on the verge of slipping, or at the critical angle θ_c. $\boxed{\text{For } \theta \le \theta_c,\ f \le f_{s\,\max} = \mu_s n}$.

(c) Recognize that when the y axis is chosen perpendicular to the incline as shown above, $a_y = 0$ and we find $\Sigma F_y = n - mg\cos\theta = ma_y = 0$ or $n = mg\cos\theta$

Also, when static conditions still prevail, but the coin is on the verge of slipping, we have $a_x = 0$, $\theta = \theta_c$, and $f = f_{s\,\max} = \mu_s n = \mu_s mg\cos\theta_c$. Then, Newton's second law becomes

$$\Sigma F_x = mg\sin\theta_c - \mu_s mg\cos\theta_c = ma_x = 0$$

and

$$\mu_s \cancel{mg}\cos\theta_c = \cancel{mg}\sin\theta_c \quad \text{yielding} \quad \mu_s = \frac{\sin\theta_c}{\cos\theta_c} = \boxed{\tan\theta_c}$$

(d) Once the coin starts to slide, kinetic conditions prevail and the friction force is

$$f = f_k = \mu_k n = \mu_k mg\cos\theta$$

At $\theta = \theta_c' < \theta_c$, the coin slides with constant velocity, and $a_x = 0$ again. Under these conditions, Newton's second law gives

$$\Sigma F_x = mg\sin\theta_c' - \mu_k mg\cos\theta_c' = ma_x = 0$$

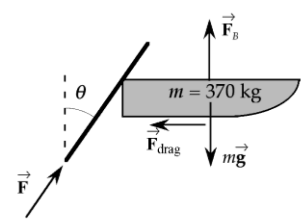
and

$$\mu_k \cancel{mg}\cos\theta_c' = \cancel{mg}\sin\theta_c'$$

yielding

$$\mu_k = \frac{\sin\theta_c'}{\cos\theta_c'} = \boxed{\tan\theta_c'}$$

4.71 (a) When the pole exerts a force downward and toward the rear on the lakebed, the lakebed exerts an oppositely directed force of equal magnitude, F, on the end of the pole.



As the boat floats on the surface of the lake, its vertical acceleration is $a_y = 0$. Thus, Newton's second law gives the magnitude of the buoyant force, F_B, as

$$\Sigma F_y = F_B + F\cos\theta - mg = 0$$

and, with $\theta = 35.0°$,

$$F_B = mg - F\cos\theta = (370 \text{ kg})(9.80 \text{ m/s}^2) - (240 \text{ N})\cos 35.0°$$

or

$$F_B = 3.43 \times 10^3 \text{ N} = \boxed{3.43 \text{ kN}}$$

(b) Applying Newton's second law to the horizontal motion of the boat gives

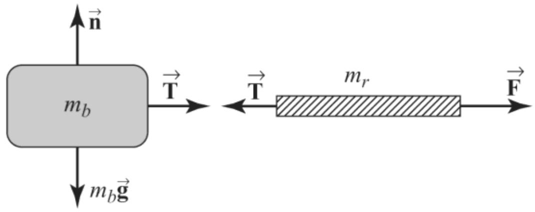
$$\Sigma F_x = F\sin\theta - \vec{F}_{drag} = ma_x \quad \text{or} \quad a_x = \frac{(240 \text{ N})\sin 35.0° - 47.5 \text{ N}}{370 \text{ kg}} = 0.244 \text{ m/s}^2$$

After an elapsed time $t = 0.450$ s, $v_x = v_{0x} + a_x t$ gives the velocity of the boat as

$$v_x = 0.857 \text{ m/s} + (0.244 \text{ m/s}^2)(0.450 \text{ s}) = \boxed{0.967 \text{ m/s}}$$

(c) If angle θ increased while the magnitude of $\vec{\mathbf{F}}$ remained constant, the vertical component of this force would decrease. $\boxed{\text{The buoyant force would have to increase}}$ to support more of the weight of the boat and its contents. At the same time, the horizontal component of $\vec{\mathbf{F}}$ would increase, which would $\boxed{\text{increase the acceleration}}$ of the boat.

4.72 (a)



(b) Applying Newton's second law to the rope yields

$$\Sigma F_x = ma_x \quad \Rightarrow \quad F - T = m_r a \quad \text{or} \quad T = F - m_r a \qquad [1]$$

Then, applying Newton's second law to the block, we find

$$\Sigma F_x = ma_x \quad \Rightarrow T = m_b a \quad \text{or} \quad F - m_r a = m_b a$$

which gives

$$\boxed{a = \frac{F}{m_b + m_r}}$$

(c) Substituting the acceleration found above back into equation [1] gives the tension at the left end of the rope as

$$T = F - m_r a = F - m_r\left(\frac{F}{m_b + m_r}\right) = F\left(\frac{m_b + \cancel{m_r} - \cancel{m_r}}{m_b + m_r}\right)$$

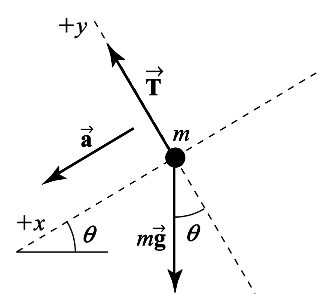
or

$$\boxed{T = \left(\frac{m_b}{m_b + m_r}\right)F}$$

(d) From the result of (c) above, we see that as m_r approaches zero, T approaches F. Thus,

$\boxed{\text{the tension in a cord of negligible mass is constant along its length}}$.

4.73 Choose the positive x axis to be down the incline and the y axis perpendicular to this as shown in the free-body diagram of the toy. The acceleration of the toy then has components of



$$a_y = 0, \text{ and } a_x = \frac{\Delta v_x}{\Delta t} = \frac{+30.0 \text{ m/s}}{6.00 \text{ s}} = +5.00 \text{ m/s}^2$$

Applying the second law to the toy gives:

(a) $\Sigma F_x = mg\sin\theta = ma_x \qquad \Rightarrow \qquad \sin\theta = ma_x/mg = a_x/g$,

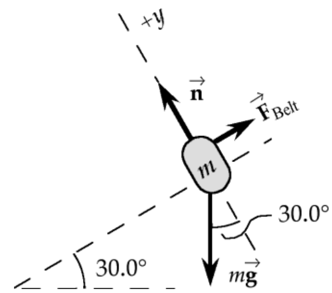
and

$$\theta = \sin^{-1}\left(\frac{a_x}{g}\right) = \sin^{-1}\left(\frac{5.00\ \text{m/s}^2}{9.80\ \text{m/s}^2}\right) = \boxed{30.7^\circ}$$

(b) $\Sigma F_y = T - mg\cos\theta = ma_y = 0$, or

$$T = mg\cos\theta = \ 0.100\ \text{kg}\ \ 9.80\ \text{m/s}^2\ \cos 30.7^\circ = \boxed{0.843\ \text{N}}$$

4.74 The sketch at the right gives the free-body diagram of the person. The scale simply reads the magnitude of the normal force exerted on the student by the seat. From Newton's second law, we obtain



$$\Sigma F_y = ma_y = 0 \quad \Rightarrow \quad n - mg\cos 30.0^\circ = 0$$

or

$$n = mg\cos\theta = \ 200\ \text{lb}\ \cos 30.0^\circ = \boxed{173\ \text{lb}}$$

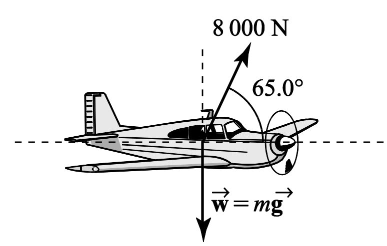
4.75 The acceleration the car has as it is coming to a stop is

$$a = \frac{v^2 - v_0^2}{2\ \Delta x} = \frac{0 -\ 35\ \text{m/s}\ ^2}{2\ 1\,000\ \text{m}} = -0.61\ \text{m/s}^2$$

Thus, the magnitude of the total retarding force acting on the car is

$$F = m|a| = \left(\frac{w}{g}\right)|a| = \left(\frac{8\,820\ \text{N}}{9.80\ \text{m/s}^2}\right)\ 0.61\ \text{m/s}^2 \ = \boxed{5.5\times10^2\ \text{N}}$$

4.766 (a) In the vertical direction, we have



$$\Sigma F_y = \ 8\,000\ \text{N}\ \sin 65.0^\circ - w = ma_y = 0$$

so $\quad w = \ 8\,000\ \text{N}\ \sin 65.0^\circ = \boxed{7.25\times10^3\ \text{N}}$

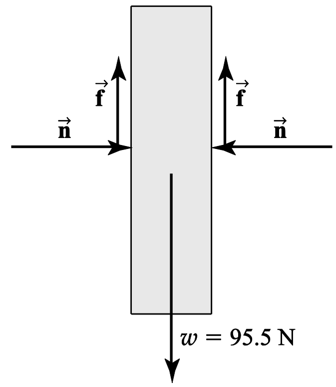
(b) Along the horizontal, Newton's second law yields

$$\Sigma F_x = \ 8\,000\ \text{N}\ \cos 65.0^\circ = ma_x = \left(\frac{w}{g}\right)a_x$$

or

$$a_x = \frac{g\left[\ 8\,000\ \text{N}\ \cos 65.0^\circ\right]}{w} = \frac{9.80\ \text{m/s}^2\ \ 8\,000\ \text{N}\ \cos 65.0^\circ}{7.25\times10^3\ \text{N}} =$$

4.77 Since the board is in equilibrium, $\Sigma F_x = 0$ and we see that the normal forces must have the same magnitudes on both sides of the board. Also, if the minimum normal forces (compression forces) are being applied, the board is on the verge of slipping and the friction force on each side is $f = (f_s)_{max} = \mu_s n$



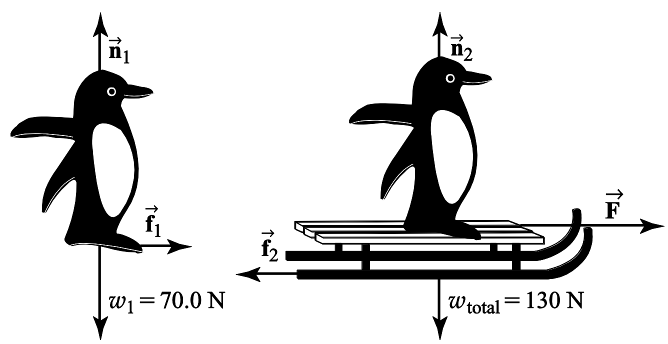
The board is also in equilibrium in the vertical direction, so

$$\Sigma F_y = 2f - w = 0, \quad \text{or } f = \frac{w}{2}$$

The minimum compression force needed is then

$$n = \frac{f}{\mu_s} = \frac{w}{2\,\mu_s} = \frac{95.5\text{ N}}{2\ 0.663} = \boxed{72.0\text{ N}}$$

4.78 Consider the two free-body diagrams, one of the penguin alone and one of the combined system consisting of penguin plus sled.



The normal force exerted on the penguin by the sled is

$$n_1 = w_1 = m_1 g$$

and the normal force exerted on the combined system by the ground is

$$n_2 = w_{total} = m_{total} g = 130\text{ N}$$

The penguin is accelerated forward by the static friction force exerted on it by the sled. When the penguin is on the verge of slipping, this acceleration is

$$a_{\max} = \frac{f_{1\ \max}}{m_1} = \frac{\mu_s n_1}{m_1} = \frac{\mu_s \left(\cancel{m_1} g\right)}{\cancel{m_1}} = \mu_s g = (0.700)(9.80\text{ m/s}^2) = 6.86\text{ m/s}^2$$

Since the penguin does not slip on the sled, the combined system must have the same acceleration as the penguin. Applying Newton's second law to this system gives

$$\Sigma F_x = F - f_2 = m_{total}\, a_{\max} \qquad \text{or} \qquad F = f_2 + m_{total}\, a_{\max} = \mu_k \;\; w_{total} + \left(\frac{w_{total}}{g}\right) a_{\max}$$

which yields

$$F = 0.100 \quad 130\text{ N} + \left(\frac{130\text{ N}}{9.80\text{ m/s}^2}\right) 6.86\text{ m/s}^2 = \boxed{104\text{ N}}$$

4.79 First, we will compute the needed accelerations:

(1) Before it starts to move:

$$a_y = 0$$

(2) During the first 0.80 s:

$$a_y = \frac{v_y - v_{0y}}{t} = \frac{1.2\text{ m/s} - 0}{0.80\text{ s}} = 1.5\text{ m/s}^2$$

(3) While moving at constant velocity:

$$a_y = 0$$

(4) During the last 1.5 s:

$$a_y = \frac{v_y - v_{0y}}{t} = \frac{0 - 1.2\text{ m/s}}{1.5\text{ s}} = -0.80\text{ m/s}^2$$

The spring scale reads the normal force the scale exerts on the man. Applying Newton's second law to the vertical motion of the man gives:

$$\Sigma F_y = n - mg = ma_y \qquad \text{or} \qquad n = m \;\; g + a_y$$

(a) When $a_y = 0$,

$$n = 72\text{ kg} \quad 9.80\text{ m/s}^2 + 0 = \boxed{7.1 \times 10^2\text{ N}}$$

(b) When $a_y = 1.5\text{ m/s}^2$,

$$n = 72\text{ kg} \quad 9.80\text{ m/s}^2 + 1.5\text{ m/s}^2 = \boxed{8.1 \times 10^2\text{ N}}$$

(c) When $a_y = 0$,

$$n = 72\text{ kg} \quad 9.80\text{ m/s}^2 + 0 = \boxed{7.1 \times 10^2\text{ N}}$$

(d) When $a_y = -0.80 \ \text{m/s}^2$,

$$n = \ 72 \text{ kg} \quad 9.80 \ \text{m/s}^2 - 0.80 \ \text{m/s}^2 \quad = \boxed{6.5 \times 10^2 \text{N}}$$

4.80 The friction force exerted on the mug by the moving tablecloth is the only horizontal force the mug experiences during this process. Thus, the horizontal acceleration of the mug will be

$$a_{mug} = \frac{f_k}{m_{mug}} = \frac{0.100 \text{ N}}{0.200 \text{ kg}} = 0.500 \ \text{m/s}^2$$

The cloth and the mug both start from rest ($v_{0x} = 0$) at time $t = 0$. Then, at time $t > 0$, the horizontal displacements of the mug and cloth are given by $\Delta x = v_{0x}t + \frac{1}{2}a_x t^2$ as:

$$\Delta x_{mug} = 0 + \tfrac{1}{2} \ 0.500 \ \text{m/s}^2 \ t^2 = \ 0.250 \ \text{m/s}^2 \ t^2$$

and

$$\Delta x_{cloth} = 0 + \tfrac{1}{2} \ 3.00 \ \text{m/s}^2 \ t^2 = \ 1.50 \ \text{m/s}^2 \ t^2$$

In order for the edge of the cloth to slip under the mug, it is necessary that $\Delta x_{cloth} = \Delta x_{mug} + 0.300 \text{ m}$, or

$$1.50 \ \text{m/s}^2 \ t^2 = \ 0.250 \ \text{m/s}^2 \ t^2 + 0.300 \text{ m}$$

The elapsed time when this occurs is

$$t = \sqrt{\frac{0.300 \text{ m}}{1.50 - 0.250 \quad \text{m/s}^2}} = 0.490\text{s}$$

At this time, the mug has moved a distance of

$$\Delta x_{mug} = \ 0.250 \ \text{m/s}^2 \quad 0.490 \text{ s} \ ^2 = 6.00 \times 10^{-2} \ \text{m} = \boxed{6.00 \text{ cm}}$$

4. 81 (a) Consider the first free-body diagram in which Chris and the chair treated as a combined system. The weight of this system is $w_{total} = 480\text{ N}$, and its mass is

$$m_{total} = \frac{w_{total}}{g} = 49.0\text{ kg}$$

Taking upward as positive, the acceleration of this system is found from Newton's second law as

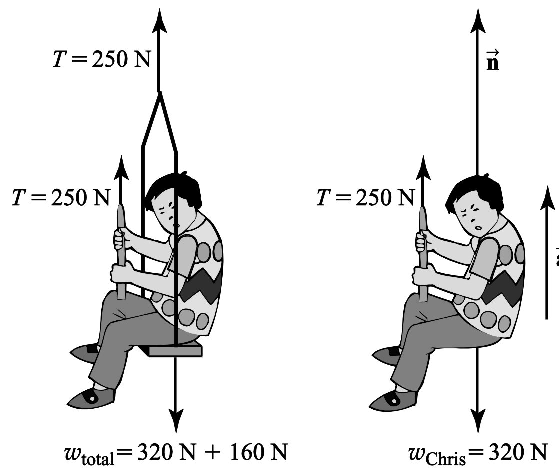
$$\Sigma F_y = 2T - w_{total} = m_{total}\, a_y$$

Thus

$$a_y = \frac{2\ 250\text{ N} - 480\text{ N}}{49.0\text{ kg}} = +0.408\ \text{m/s}^2$$

or

$$\boxed{0.408\ \text{m/s}^2\ \text{upward}}$$



(b) The downward force that Chris exerts on the chair has the same magnitude as the upward normal force exerted on Chris by the chair. This is found from the free-body diagram of Chris alone as

$$\Sigma F_y = T + n - w_{Chris} = m_{Chris}\, a_y$$

so

$$n = m_{Chris}\, a_y + w_{Chris} - T$$

Hence,

$$n = \left(\frac{320\text{ N}}{9.80\ \text{m/s}^2}\right)\ 0.408\ \text{m/s}^2\ + 320\text{ N} - 250\text{ N} = \boxed{83.3\text{ N}}$$

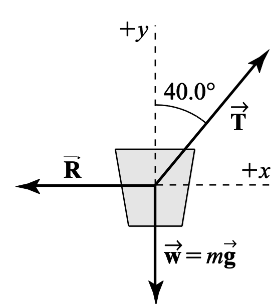
4.82 Let $\vec{\mathbf{R}}$ represent the horizontal force of air resistance. Since the helicopter and bucket move at constant velocity, $a_x = a_y = 0$.

The second law then gives:

$$\Sigma F_y = T\cos 40.0° - mg = 0 \quad \text{or} \quad T = \frac{mg}{\cos 40.0°}$$

Also,

$$\Sigma F_x = T\sin 40.0° - R = 0 \quad \text{or} \quad R = T\sin 40.0°$$



Thus,

$$R = \left(\frac{mg}{\cos 40.0°} \right) \sin 40.0° = \; 620\ \text{kg} \quad 9.80\ \text{m/s}^2 \;\; \tan 40.0° = \boxed{5.10 \times 10^3\ \text{N}}$$