20. \( m = \frac{W}{g} = \frac{0.80 \times 10^3 \text{ N}}{9.8 \text{ N/kg}} = 82 \text{ kg} \)

21. (a) Set the weight of the mass equal to the force in Hooke’s law. 
\( W = F \)
\( mg = kx \)
\( k = \frac{mg}{x} \)
\( (1.4 \text{ kg}) \left( 9.8 \frac{\text{ N}}{\text{ kg}} \right) = 7.2 \text{ cm} \)
\( = 1.9 \text{ N/cm} \)

(b) Solve for \( m \) in the equation for \( k \) found in part (a). 
\( m^2 = \frac{kx^2}{g} \left( \frac{mg}{x_1} \right) \left( \frac{x_2}{x_1} \right) = \frac{12.2 \text{ cm}}{7.2 \text{ cm}} (1.4 \text{ kg}) = 2.4 \text{ kg} \)

22. (a) Multiply the extension per mass by the mass to find the maximum extension required. 
\( \left( \frac{1.0 \text{ mm}}{25 \text{ g}} \right) (5.0 \text{ kg}) \left( \frac{1000 \text{ g}}{1 \text{ kg}} \right) \left( \frac{1 \text{ m}}{1000 \text{ mm}} \right) = 0.20 \text{ m} \)

(b) Set the weight of the mass equal to the force in Hooke’s law. 
\( W = F \)
\( mg = kx \)
\( k = \frac{mg}{x} \)
\( (5.0 \text{ kg}) \left( 9.8 \frac{\text{ N}}{\text{ kg}} \right) = \frac{0.20 \text{ m}}{250 \text{ N/m}} \)

26. Set the forces on the spaceship due to the Earth and the Moon equal. Use magnitudes. (The forces are collinear.)
\( F_{\text{E}} = F_{\text{M}} \)
\( GM_{\text{E}} m = GM_{\text{M}} m \)
\( \frac{r_{\text{E}}^2}{r_{\text{M}}^2} = \frac{M_{\text{E}}}{M_{\text{M}}} \)
\( r_{\text{E}} = r_{\text{M}} \sqrt{\frac{M_{\text{E}}}{0.0123 M_{\text{E}}}} \)
\( = 9.02 r_{\text{M}} \)

Find the percentage.
\( \frac{r_{\text{E}}}{r_{\text{E}} + r_{\text{M}}} = \frac{9.02 r_{\text{M}}}{9.02 r_{\text{M}} + r_{\text{M}}} = 0.900 \)

The distance from the Earth is 90.0% of the Earth-Moon distance.

27. (a) \( W = mg = \frac{GM_{\text{E}} m}{r^2} = \frac{6.673 \times 10^{-11} \frac{\text{ N} \cdot \text{m}^2}{\text{kg}^2}}{(5.975 \times 10^{24} \text{ kg})(320 \text{ kg})} = 250 \text{ N} \)
(b) \[ W = mg = (320 \text{ kg}) \left( 9.8 \frac{\text{N}}{\text{kg}} \right) = 3100 \text{ N} \]

(c) According to Newton's third law, the satellite exerts a force on the Earth equal and opposite to the force the Earth exerts on it, that is, \( 250 \text{N toward the satellite} \).

35. (a) To just get the block to move, the force must be equal to the maximum force of static friction.

\[
F = f_{\text{max}} = \mu_s N = \mu_s mg
\]

\[
\mu_s = \frac{F}{mg} = \frac{12.0 \text{ N}}{(3.0 \text{ kg}) (9.8 \frac{\text{N}}{\text{kg}})} = 0.41
\]

(b) The maximum static frictional force is now proportional to the total mass of the two blocks.

\[
F = \mu_s mg = 0.41 (3.0 \text{ kg} + 7.0 \text{ kg}) \left( 9.8 \frac{\text{N}}{\text{kg}} \right) = 40 \text{ N}
\]

36. (a) Since the sleigh is moving with constant speed, the net force acting on the sleigh is \( \text{zero} \).

(b) The force of magnitude \( T \) must be equal to the force of kinetic friction, since \( F_{\text{net}} = 0 \) (constant speed).

\[
T = f_k = \mu_k mg
\]

\[
\mu_k = \frac{T}{mg} = \frac{150 \text{ N}}{250 \text{ N}} = 0.60
\]

37. (a) The force static friction is greater than the applied force, so

\[ f_k > F \]

\[ \mu_s N > F \]

\[ \mu_s > \frac{F}{N} \]

\[ \mu_s > \frac{120 \text{ N}}{250 \text{ N}} \]

\[ \mu_s > 0.48 \]

(b) \[ \mu_s = \frac{F}{N} = \frac{150 \text{ N}}{250 \text{ N}} = 0.60 \]

(c) \[ \mu_k = \frac{F}{N} = \frac{120 \text{ N}}{250 \text{ N}} = 0.48 \]

44. (a) All forces are co-linear. The magnitude of the force of static friction on block A due to the floor must be equal to the magnitude of the tension in the cord.

\[
T = f_{\text{sA}} = \mu_A N = \mu_A mg
\]

The magnitude of the applied force must be equal to the magnitude of the tension in the cord plus the magnitude of the force of static friction on block B due to the floor.

\[
F = T + f_{\text{sB}} = \mu_A mg + \mu_B mg = mg (\mu_A + \mu_B) = (2.0 \text{ kg}) \left( 9.8 \frac{\text{N}}{\text{kg}} \right) (0.45 + 0.30) = 15 \text{ N}
\]

(b) \[ T = \mu_A mg = 0.45 (2.0 \text{ kg}) \left( 9.8 \frac{\text{N}}{\text{kg}} \right) = 8.8 \text{ N} \]
46. (a) The tension due to the weight of the potatoes is divided evenly between the two sets of scales.
\[ T = \frac{W}{2} \]
\[ = \frac{220.0 \, \text{N}}{2} \]
\[ = 110.0 \, \text{N} \]

(b) Scales B and D will read 75.00 N as before. Scales A and C will read an additional 5.0 N due to the weights of B and D, respectively.
\[ T_A = 110.0 \, \text{N} + 5.0 \, \text{N} = 115.0 \, \text{N} = T_C \]
\[ T_B = 110.0 \, \text{N} = T_D \]

47. (a) The mass connected to the lower spring exerts a force on the lower spring equal to its weight, \( W \). The spring stretches an amount \( x = \frac{F}{k} = \frac{W}{k} \). The lower spring exerts a force on the upper spring equal to \( F = W \), and causes it to stretch by \( x = \frac{F}{k} = \frac{W}{k} \). Thinking of the two springs as a single spring:
\[ 2x = \frac{F}{k} + \frac{F}{k} = \frac{2F}{k} = x', \text{ so } F = \frac{k}{2} x' = k'x'. \]
Therefore, \( \frac{k}{2} = k' \), the effective spring constant.

(b) Sum the forces on the mass.
\[ F + F - W = 0 \]
\[ kx + kx - W = 0 \]
\[ 2kx - W = 0 \]
\[ W = 2kx \]
\[ = k'x \]
Therefore, \( \frac{2k}{k'} = k' \), the effective spring constant.

53. (a) The system with the two weights:
Sum the vertical forces on the masses. The masses are in static equilibrium. (The masses are identical.)
The left weight:
\[ \sum F_y = T - W = 0 \]
\[ T = W = 550 \, \text{N} \]
The right weight:
\[ \sum F_y = T - W = 0 \]
\[ T = W = 550 \, \text{N} \]
So, since the tension is 550 N, the scale reads 550 N.
The system with the single weight:
\[ \sum F_y = T - W = 0 \]
\[ T = W = 550 \, \text{N} \]
In both cases the two ropes pull on the scale with forces of 550N in opposite directions, so the scales give the same reading.

(b) \[ T = W = 550 \, \text{N} \]

Chapter 3

19. Treat the last 10 freight cars as a system.
The vertical forces cancel.
\[ \sum F_y = N - mg = ma_y = 0 \]
Let the direction of motion be \(+x\).
The force exerted on the eleventh car by the tenth is the tension at the coupler, \( T_{11} \).
The force is $1.0 \times 10^5$ N in the direction of motion.

20. Use the expressions for $a_y$ and $T$ found in Example 3.7.

(a) $a_y = \frac{(m_2 - m_1)g}{m_2 + m_1} = \frac{(5.0 \text{ kg} - 3.0 \text{ kg})(9.8 \text{ m/s}^2)}{5.0 \text{ kg} + 3.0 \text{ kg}} = 2.5 \text{ m/s}^2$

(b) $T = \frac{2m_1m_2}{m_1 + m_2}g = \frac{2(3.0 \text{ kg})(5.0 \text{ kg})}{3.0 \text{ kg} + 5.0 \text{ kg}} \left( \frac{9.8 \text{ m/s}^2}{2} \right) = 37 \text{ N}$

22. Use Newton’s second law for the vertical direction.

$\sum F_y = T - mg = ma_y$

Solve for $T$.

$T = m(a_y + g) = (2010 \text{ kg}) \left( 1.5 \frac{\text{ m}}{\text{s}^2} + 9.8 \frac{\text{ m}}{\text{s}^2} \right) = 22.7 \text{ kN}$

23. Use Newton’s second law for the vertical direction.

$\sum F_y = T - mg = ma_y$

Solve for $T$.

$T = m(a_y + g) = (2010 \text{ kg}) \left( -1.5 \frac{\text{ m}}{\text{s}^2} + 9.8 \frac{\text{ m}}{\text{s}^2} \right) = 17 \text{ kN}$

30. (a) Since the train slows down, the acceleration is negative.

$\frac{v_x - v_{0x}}{\Delta t} = a_x \Delta t$

$v_x = v_{0x} + a_x \Delta t$

$= 22 \frac{\text{ m}}{\text{s}} + \left( -1.4 \frac{\text{ m}}{\text{s}^2} \right)(8.0 \text{ s})$

$= 11 \text{ m/s}$

(b) $x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 = 0 + \left( 22 \frac{\text{ m}}{\text{s}} \right)(8.0 \text{ s}) + \frac{1}{2} \left( -1.4 \frac{\text{ m}}{\text{s}^2} \right)(8.0 \text{ s})^2 = 130 \text{ m}$

36. $v_x^2 - v_{0x}^2 = 2a_x \Delta x$

$a_x = \frac{v_x^2 - v_{0x}^2}{2\Delta x}$

$a_{x1} = a_{x2}$ for the same maximum braking force.

$\frac{v_{x1}^2 - v_{0x1}^2}{2\Delta x_1} = \frac{v_{x2}^2 - v_{0x2}^2}{2\Delta x_2} \quad (v_{x1} = v_{x2} = 0)$

$\frac{v_{0x1}^2}{\Delta x_1} = \frac{v_{0x2}^2}{\Delta x_2}$

$\Delta x_2 = \left( \frac{v_{0x2}}{v_{0x1}} \right)^2 \Delta x_1$

$= \left( \frac{60.0 \text{ m/h}}{30.0 \text{ m/h}} \right)^2 (12 \text{ m})$

$= 48 \text{ m}$
45. \( v_y^2 - v_{0y}^2 = -2g\Delta y \)
\[
v_y = \sqrt{v_{0y}^2 - 2g\Delta y}
\]
\[
= \sqrt{10.0 \text{ m/s}^2 - 2 \left( 9.8 \text{ m/s}^2 \right) \left(-40.8 \text{ m}\right)}
\]
\[
= 30.0 \text{ m/s}
\]

46. (a) \[ |\Delta y| = \frac{1}{2} gt^2 \]
\[
= \frac{1}{2} \left( 9.8 \text{ m/s}^2 \right) (3.0 \text{ s})^2
\]
\[
= 44 \text{ m}
\]
(b) \( v_y^2 = -2g\Delta y \)
\[
v_y = \sqrt{-2g\Delta y}
\]
\[
= \sqrt{-2 \left( 9.8 \text{ m/s}^2 \right) (-2.5 \text{ m})}
\]
\[
= 7.0 \text{ m/s}
\]
(c) \[ |v_y| = gt \left( 9.8 \text{ m/s}^2 \right) (3.0 \text{ s}) = 29 \text{ m/s} \]

50. (a) \( F_d = bn^2 = \left( 0.14 \text{ N/s}^2 \text{ m}^2 \right) \left( 64 \text{ m/s} \right)^2 = 570 \text{ N} \)

The force of air resistance is directed opposite the diver’s motion, so \( F_d = 570 \text{ N up} \).

(b) Use Newton’s second law. Up is the positive direction.
\[ \sum F_y = F_d - W = ma_y \]
\[
a_y = \frac{F_d - W}{m} = \frac{F_d - mg}{m} = \frac{F_d}{m} - g = \frac{570 \text{ N}}{120 \text{ kg}} - 9.8 \frac{\text{m}}{\text{s}^2} = -5.0 \frac{\text{m}}{\text{s}^2}
\]
The acceleration is \( 5.0 \text{ m/s}^2 \) downward.

(c) Set \( W = F_d \), or \( mg = bh_v^2 \), and solve for \( v_t \).
\[
v_t = \sqrt{\frac{mg}{b}} = \sqrt{\frac{\left( 120 \text{ kg} \right) \left( 9.8 \text{ m/s}^2 \right)}{0.14 \text{ N/s}^2 \text{ m}^2}} = 92 \text{ m/s}
\]

52. (a) \[ \frac{\Delta g}{g} = 0.01000 = \frac{g - g'}{g} = 1 - \frac{g'}{g} = 1 - \frac{GM_E}{G_E} - \frac{(R_E + h)^2}{(R_E)^2} = 1 - \frac{R_E^2}{(1 + \frac{h}{R_E})^2}
\]

Solve for \( h \).
\[ 0.01000 = 1 - \frac{1}{1 + \left(\frac{h}{R_E}\right)^2} \]

\[ \frac{1}{\left(1 + \frac{h}{R_E}\right)^2} = 0.99000 \]

\[ \frac{1}{0.99000} = \left(1 + \frac{h}{R_E}\right)^2 \]

\[ \pm \sqrt{\frac{1}{0.99000}} = 1 + \frac{h}{R_E} \]

\[ \frac{h}{R_E} = \sqrt{\frac{1}{0.99000}} - 1 \]

\[ h = R_E \left( \sqrt{\frac{1}{0.99000}} - 1 \right) \]

\[ = (6.371 \times 10^3 \text{ km}) \left( \sqrt{\frac{1}{0.99000}} - 1 \right) \]

\[ = 32 \text{ km} \]

The positive root was chosen because \( h > 0 \) and \( R_E > 0 \).

(b) The drag force is much larger than variations in the gravitational force due to changes to \( g \), so air resistance is more significant.

53. (a) The elevator is accelerating downward, so \( a_y = -0.50 \text{ m/s}^2 \).

\[ W' = \frac{W}{g} (g + a_y) = \frac{598 \text{ N}}{9.80 \frac{\text{m}}{\text{s}^2}} \left( 1 + \frac{-0.50 \frac{\text{m}}{\text{s}^2}}{9.80 \frac{\text{m}}{\text{s}^2}} \right) = 567 \text{ N} \]

(b) The elevator is accelerating upward, so \( a_y = 0.50 \text{ m/s}^2 \).

\[ W' = \frac{W}{g} (g + a_y) = \frac{598 \text{ N}}{9.80 \frac{\text{m}}{\text{s}^2}} \left( 1 + \frac{0.50 \frac{\text{m}}{\text{s}^2}}{9.80 \frac{\text{m}}{\text{s}^2}} \right) = 629 \text{ N} \]

62. Choose the +x-axis to the right and +y-axis up. Use Newton’s second law.

(a) For \( m_1 \):

\[ \sum F_{1y} = N - W_1 = N - m_1 g = 0, \text{ so } N = m_1 g. \]

\[ \sum F_{1x} = T - f_k = T - \mu_k N = T - \mu_k m_1 g = m_1 a_{1x} \]

For \( m_2 \):

\[ \sum F_{2x} = 0 \]

\[ \sum F_{2y} = T - W_2 = T - m_2 g = m_2 a_{2y} \]

Now, \( a_{1x} \) and \( a_{2y} \) must be equal in magnitude, otherwise the cord will compress or expand. \( a_{1x} \) is in the +x-direction and \( a_{2y} \) is in the -y-direction. So, let \( a = a_{1x} = -a_{2y} \). Then,

\[ T - \mu_k m_1 g = m_1 a \] and \( T - m_2 g = -m_2 a \).

Subtract the second equation from the first and solve for \( a \).

\[ -\mu_k m_1 g + m_2 g = m_1 a + m_2 a \]

\[ g (m_2 - \mu_k m_1) = a (m_1 + m_2) \]

\[ a = \frac{m_2 - \mu_k m_1}{m_1 + m_2} g \]

Find \( T \).
\[ T - m_2 g = -m_2 a \]
\[ T = m_2 g - m_2 \frac{m_2 - \mu_k m_1}{m_1 + m_2} \]
\[ = \frac{m_2 (m_1 + m_2) - m_2 (m_2 - \mu_k m_1)}{m_1 + m_2} g \]
\[ = \frac{m_1 m_2 + m_2^2 - m_2^2 + m_2 m_2 \mu_k}{m_1 + m_2} g \]
\[ T = (1 + \mu_k) \frac{m_1 m_2}{m_1 + m_2} g \]