Chapter 4
The Laws of Motion

Quick Quizzes

1. **(a)** True. Motion requires no force. Newton's first law says an object in motion continues to move by itself in the absence of external forces.

(b) False. It is possible for forces to act on an object with no resulting motion if the forces are balanced.

2. **(a)** True. If a single force acts on an object, it must accelerate. From Newton's second law, $\vec{\mathbf{a}} = \Sigma \vec{\mathbf{F}} / m$, and a single force must represent a non-zero net force.

(b) True. If an object accelerates, at least one force must act on it.

(c) False. If an object has no acceleration, you cannot conclude that no forces act on it. In this case, you can only say that the net force on the object is zero.

3. False. If the object begins at rest or is moving with a velocity with only an x component, the net force in the x direction causes the object to move in the x direction. In any other case, however, the motion of the object involves velocity components in directions other than x. Thus, the direction of the velocity vector is not generally along the x axis. What we can say with confidence is that a net force in the x direction causes the object to *accelerate* in the x direction.

4. (a). Because the value of g is smaller on the Moon than on the Earth, more mass of gold would be required to represent 1 newton of weight on the Moon. Thus, your friend on the Moon is richer, by about a factor of 6!

5. (c) and (d). Newton's third law states that the car and truck will experience equal magnitude (but oppositely directed) forces. Newton's second law states that acceleration is inversely proportional to mass when the force is constant. Thus, the lower mass vehicle (the car) will experience the greater acceleration.

6. (c). The scale is in equilibrium in both situations, so it experiences a net force of zero. Because each person pulls with a force F and there is no acceleration, each person is in equilibrium. Therefore, the tension in the ropes must be equal to F. In case (i), the person on the right pulls with force F on a spring mounted rigidly to a brick wall. The resulting tension F in the rope causes the scale to read a force F. In case (ii), the person on the left can be modeled as simply holding the rope tightly while the person on the right pulls. Thus, the person on the left is doing the same thing that the wall does in case (i). The resulting scale reading is the same whether there is a wall or a person holding the left side of the scale.

7. (c). The tension in the rope has a vertical component that supports part of the total weight of the child and sled. Thus, the upward normal force exerted by the ground is less than the total weight.

8. (b). Friction forces are always parallel to the surfaces in contact, which, in this case, are the wall and the cover of the book. This tells us that the friction force is either upward or downward. Because the tendency of the book is to fall due to gravity, the friction force must be in the upward direction.

9. (b). The static friction force between the bottom surface of the crate and the surface of the truck bed is the net horizontal force on the crate that causes it to accelerate. It is in the same direction as the acceleration, to the east.

10. (b). It is easier to attach the rope and pull. In this case, there is a component of your applied force that is upward. This reduces the normal force between the sled and the snow. In turn, this reduces the friction force between the sled and the snow, making it easier to move. If you push from behind, with a force with a downward component, the normal force is larger, the friction force is larger, and the sled is harder to move.

Answers to Even Numbered Conceptual Questions

2. If the car is traveling at constant velocity, it has zero acceleration. Hence, the resultant force acting on it is zero.

4. The force causing the ball to rebound upward is the normal force exerted on the ball by the floor.

6. $w = mg$ and g decreases with altitude. Thus, to get a good buy, purchase it in Denver. If gold was sold by mass, it would not matter where you bought it.

8. If it has a large mass, it will take a large force to alter its motion even when floating in space. Thus, to avoid injuring himself, he should push it gently toward the storage compartment.

10. The net force acting on the object decreases as the resistive force increases. Eventually, the resistive force becomes equal to the weight of the object, and the net force goes to zero. In this condition, the object stops accelerating, and the velocity stays constant. The rock has reached its terminal velocity.

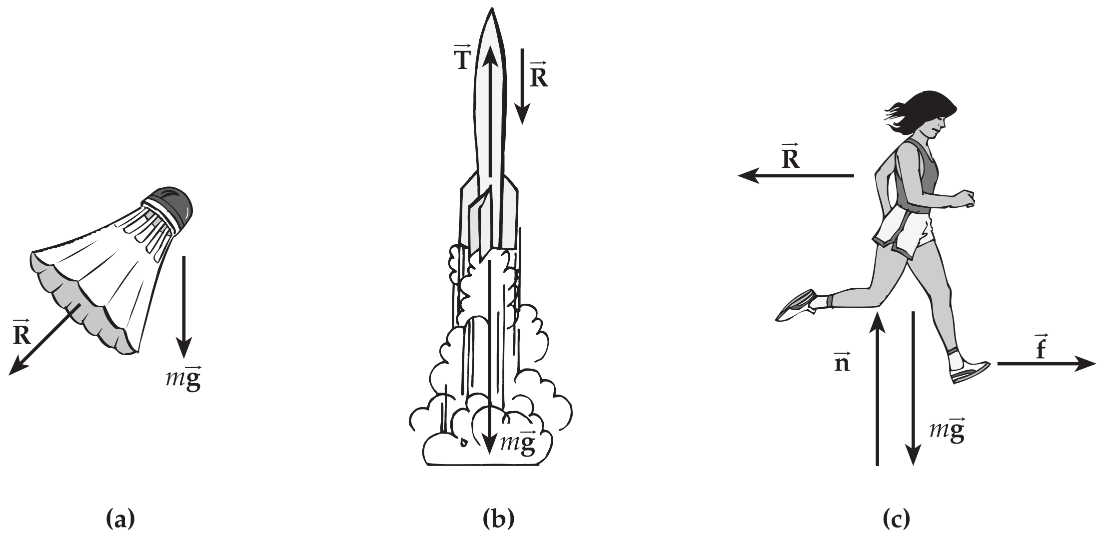
12. The barbell always exerts a downward force on the lifter equal in magnitude to the upward force that she exerts on the barbell. Since the lifter is in equilibrium, the magnitude of the upward force exerted on her by the scale (that is, the scale reading) equals the sum of her weight and the downward force exerted by the barbell. As the barbell goes through the bottom of the cycle and is being lifted upward, the scale reading exceeds the combined weights of the lifter and the barbell. At the top of the motion and as the barbell is allowed to move back downward, the scale reading is less than the combined weights. If the barbell is moving upward, the lifter can declare she has thrown it just by letting go of it for a moment. Thus, the case is included in the previous answer.

14. While the engines operate, their total upward thrust exceeds the weight of the rocket, and the rocket experiences a net upward force. This net force causes the upward velocity of the rocket to increase in magnitude (speed). The upward thrust of the engines is constant, but the remaining mass of the rocket (and hence, the downward gravitational force or weight) decreases as the rocket consumes its fuel. Thus, there is an increasing net upward force acting on a diminishing mass. This yields an acceleration that increases in time.

16. The truck's skidding distance can be shown to be $x = \dfrac{v_0^2}{2\mu_k g}$ where μ_k is the coefficient of kinetic friction and v_0 is the initial velocity of the truck. This equation demonstrates that the mass of the truck does not affect the skidding distance, but halving the velocity will decrease the skidding distance by a factor of four.

18. Because the mass of the truck is decreasing, the acceleration will increase.

20.



In the free-body diagrams give above, $\vec{\mathbf{R}}$ represents a force due to air resistance, $\vec{\mathbf{T}}$ is a force due to the thrust of the rocket engine, $\vec{\mathbf{n}}$ is a normal force, $\vec{\mathbf{f}}$ is a friction force, and the forces labeled $m\vec{\mathbf{g}}$ are gravitational forces.

Answers to Even Numbered Problems

2. 25 N

4. 1.7×10^2 N

6. 7.4 min

8. 3.1×10^2 N

10. **(a)** The gravitational force for S is greater than F
(b) The time of fall for S is less than F
(c) The times are equal **(d)** The total force on S is greater than F

12. **(a)** 799 N at 8.77° to the right of forward direction
(b) 0.266 m/s^2 in the direction of the resultant force

14. 1.59 m/s^2 at 65.2° N of E

16. 77.8 N in each wire

18. 1.7×10^2 N , 61°

20. 1.04×10^3 N rearward

22. **(a)** $T = \dfrac{mg}{\sin\theta}$ **(b)** 1.79 N

24. **(a)** 1.5 m **(b)** 1.4 m

26. 4.43 m/s^2 up the incline, 53.7 N

28. 13 N down the incline

30. 6.53 m/s^2 , 32.7 N

32. **(a)** $T > w$ **(b)** $T = w$ **(c)** $T < w$
(d) 1.85×10^4 N , Yes **(e)** 1.47×10^4 N , Yes **(f)** 1.25×10^4 N , Yes

34. **(a)** 36.8 N **(b)** 2.45 m/s^2 **(c)** 1.23 m

36. **(a)** 0 **(b)** 0.70 m/s^2

38. **(a)** -1.20 m/s^2 **(b)** 0.122 **(c)** 45.0 m

40. **(a)** 55.2° **(b)** 167 N

42. 3.17 s

44. **(a)** 0.366 m/s^2 **(b)** 1.29 m/s^2 down the incline

46. **(a)** 98.6 m **(b)** 16.4 m

48. **(a)** 0.125 m/s^2 **(b)** 39.7 N **(c)** 0.235

50. **(a)** 18.5 N **(b)** 25.8 N

52. **(a)** 2.13 s **(b)** 1.67 m

54. 2.6 m/s^2

56. 21.5 N

58. **(a)** 50.0 N **(b)** 0.500 **(c)** 25.0 N

60. 0.814

62. **(a)** 1.63 m/s^2
(b) 57.2 N tension in string connecting 5-kg and 4-kg, 24.5 N tension in string connecting 4-kg and 3-kg

64. **(b)** 9.8 N **(c)** 0.58 m/s^2

66. 1.18×10^3 N upward

68. 0.69 m/s^2

70. 173 lb

72. 23 m/s

74. **(a)** 7.25×10^3 N **(b)** 4.57 m/s^2

76. 104 N

78. 6.00 cm

80. 5.10×10^3 N

Problem Solutions

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

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

4.2 From $v = v_0 + at$, 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

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

4.3 $w = (2\ \text{tons})\left(\dfrac{2000\ \text{lbs}}{1\ \text{ton}}\right)\left(\dfrac{4.448\ \text{N}}{1\ \text{lb}}\right) = \boxed{2 \times 10^4\ \text{N}}$

4.4 $w = (38\ \text{lbs})\left(\dfrac{4.448\ \text{N}}{1\ \text{lb}}\right) = \boxed{1.7 \times 10^2\ \text{N}}$

4.5 The weight of the bag of sugar on Earth is $w_E = mg_E = (5.00\ \text{lbs})\left(\dfrac{4.448\ \text{N}}{1\ \text{lb}}\right) = 22.2\ \text{N}$. 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 $\dfrac{w_M}{w_E} = \dfrac{mg_M}{mg_E} = \dfrac{g_M}{g_E}$, so $w_M = w_E\left(\dfrac{g_M}{g_E}\right)$. Hence, the weight of the bag of sugar on the Moon is $w_M = (22.2\ \text{N})\left(\dfrac{1}{6}\right) = \boxed{3.71\ \text{N}}$. On Jupiter, its weight would be $w_J = w_E\left(\dfrac{g_J}{g_E}\right) = (22.2\ \text{N})(2.64) = \boxed{58.7\ \text{N}}$

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

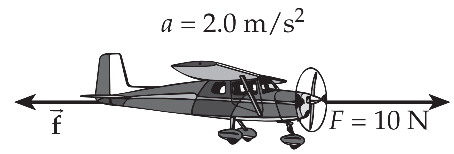
$$m = \frac{w_E}{g_E} = \frac{(5.00\ \text{lb})(4.448\ \text{N/lb})}{9.80\ \text{m/s}^2} = \boxed{2.27\ \text{kg}}$$

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



$$\Sigma F_x = F - f = 10 \text{ N} - f = (0.20 \text{ kg})(2.0 \text{ m/s}^2)$$

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

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

4.9 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

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

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

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

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

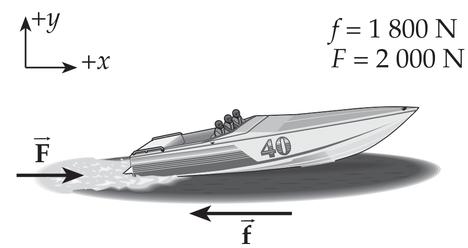
4.10 (a) The sphere has a larger mass than the feather. Hence, the sphere experiences a larger gravitational force $F_g = mg$ than does the feather.

(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.

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



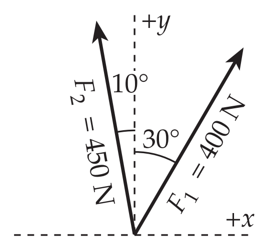
$$a = \frac{\Sigma F}{m} = \frac{2\,000 \text{ N} - 1\,800 \text{ N}}{1\,000 \text{ kg}} = \boxed{0.200 \text{ m/s}^2}$$

(b) The distance moved is

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

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

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

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

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

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

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

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

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

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

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

$$F = ma = \left(0.50 \text{ kg}\right)\left(+2.2 \times 10^4 \text{ m/s}^2\right) = +1.1 \times 10^4 \text{ N}$$

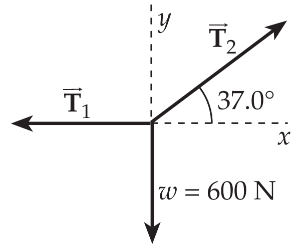
or $\vec{\mathbf{F}} = \boxed{1.1 \times 10^4 \text{ N upward}}$

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

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

Thus, $a = \dfrac{F_R}{m} = \dfrac{430 \text{ N}}{270 \text{ kg}} = 1.59 \text{ m/s}^2$ or $\vec{\mathbf{a}} = \boxed{1.59 \text{ m/s}^2 \text{ at } 65.2° \text{ N of E}}$

4.15 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:

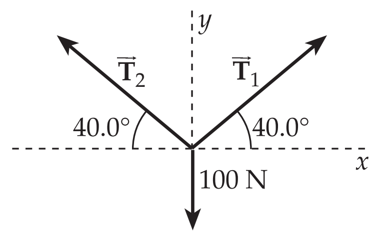
$$\Sigma F_y = 0 \text{, giving } T_2 \sin 37.0° - 600 \text{ N} = 0$$

or $\quad T_2 = \boxed{997 \text{ N in the inclined cable}}$

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

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

4.16 From $\Sigma F_x = 0$, $T_1 \cos 40.0° - T_2 \cos 40.0° = 0$

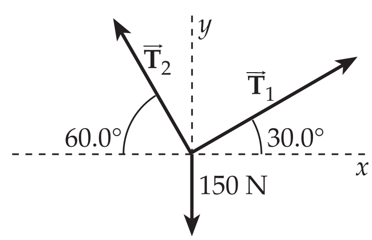


or $\quad T_1 = T_2$

Then, $\Sigma F_y = 0$ gives $2(T_1 \sin 40.0°) - 100 \text{ N} = 0$

yielding $T_1 = T_2 = \boxed{77.8 \text{ N}}$

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



or $\quad T_2 = (1.73)T_1 \qquad (1)$

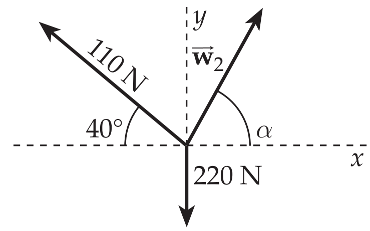
Then $\Sigma F_y = 0$ becomes

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

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

Finally, Equation (1) above gives $T_2 = \boxed{130 \text{ N in the left side cable}}$

4.18 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

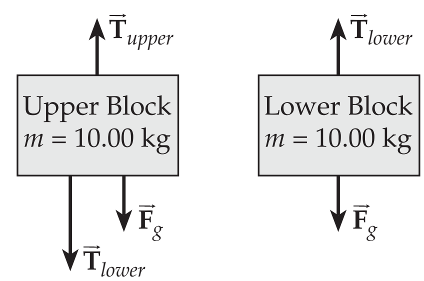
$$w_2 \sin\alpha = 220 \text{ N} - (110 \text{ N})\sin 40° \qquad (2)$$

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), $w_2 = \boxed{1.7 \times 10^2 \text{ N}}$

4.19 Free-body diagrams of the two blocks are shown at the right. Note that each block experiences a downward gravitational force $F_g = mg = 98.0$ N. Also, each has the same upward acceleration as the elevator, $a_y = +2.00 \text{ m/s}^2$



Applying Newton's 2nd law to the lower block :

$$\Sigma F_y = ma_y \quad \Rightarrow \quad T_{lower} - F_g = ma_y$$

or $$T_{lower} = F_g + ma_y = 98.0 \text{ N} + (10.0 \text{ kg})(+2.00 \text{ m/s}^2) = \boxed{118 \text{ N}}$$

Then, applying the 2nd law to the upper block

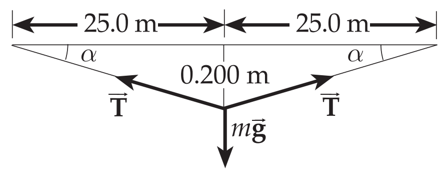
$$\Sigma F_y = ma_y \quad \Rightarrow \quad T_{upper} - T_{lower} - F_g = ma_y$$

or $$T_{upper} = T_{lower} + F_g + ma_y = 118 \text{ N} + 98.0 \text{ N} + (10.0 \text{ kg})(+2.00 \text{ m/s}^2) = \boxed{236 \text{ N}}$$

4.20 The resultant force exerted on the boat by the people is $2\left[(600\text{ N})\cos 30.0°\right] = 1.04\times10^{3}\text{ N}$ 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

$$\vec{\mathbf{f}} = \boxed{1.04\times10^{3}\text{ N in the rearward direction}}$$

4.21 $m = 1.00\text{ kg}$ and $mg = 9.80\text{ N}$



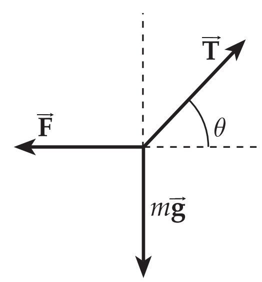
$$\alpha = \tan^{-1}\left(\frac{0.200\text{ m}}{25.0\text{ m}}\right) = 0.458°$$

Require that $\Sigma F_y = 0$,

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

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

4.22 (a) An explanation proceeding from fundamental physical principles will be best for the parents and for you. Consider forces on the bit of string touching the weight hanger as shown in the free-body diagram:



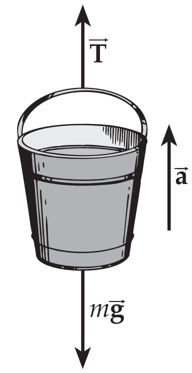
Horizontal Forces: $\Sigma F_x = 0 \Rightarrow -F + T\cos\theta = 0$

Vertical Forces: $\Sigma F_y = 0 \Rightarrow -mg + T\sin\theta = 0$

You need only the equation for the vertical forces to find that the tension in the string is given by $\boxed{T = \dfrac{mg}{\sin\theta}}$. The force the child feels gets smaller, changing from T to $T\cos\theta$, while the counterweight hangs on the string. On the other hand, the kite does not notice what you are doing and the tension in the main part of the string stays constant. You do not need a level, since you learned in physics lab to sight to a horizontal line in a building. Share with the parents your estimate of the experimental uncertainty, which you make by thinking critically about the measurement, by repeating trials, practicing in advance and looking for variations and improvements in technique, including using other observers. You will then be glad to have the parents themselves repeat your measurements.

(b) $$T = \frac{mg}{\sin\theta} = \frac{(0.132\text{ kg})(9.80\text{ m/s}^2)}{\sin 46.3°} = \boxed{1.79\text{ N}}$$

4.23 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 the second law:

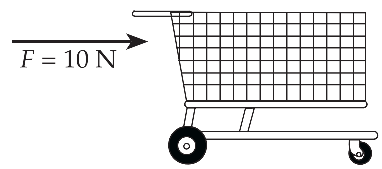


$$\Sigma F_y = ma_y$$

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

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

4.24 (a) From the second law, we find the acceleration as



$$a = \frac{F}{m} = \frac{10\ \text{N}}{30\ \text{kg}} = 0.33\ \text{m/s}^2$$

To find the distance moved, we use

$$\Delta x = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(0.33\ \text{m/s}^2)(3.0\ \text{s})^2 = \boxed{1.5\ \text{m}}$$

(b) If the shopper places her $30\ \text{N}\ (3.1\ \text{kg})$ child in the cart, the new acceleration will be $a = \dfrac{F}{m_{total}} = \dfrac{10\ \text{N}}{33\ \text{kg}} = 0.30\ \text{m/s}^2$, and the new distance traveled in 3.0 s will be

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

4.25 (a) The average acceleration is given by

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

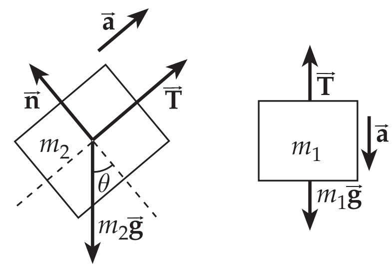
The average force is found from the second law as

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

(b) The distance traveled is:

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

4.26 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



$$m_1 a = m_1 g - T \tag{1}$$

and $$m_2 a = T - m_2 g \sin\theta \tag{2}$$

Adding these equations yields

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

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

Then, Equation (1) yields

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

4.27 (a) The resultant external force acting on this system 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:

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

(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:

$$F = ma = (2.0\ \text{kg})(7.0\ \text{m/s}^2)\text{, or } \vec{\mathbf{F}} = \boxed{14\ \text{N horizontally to the right}}$$

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

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

This gives $\quad a = 6.4 \text{ m/s}^2$

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

4.29 Choose the positive x axis to be up the incline.

Then,

$$\Sigma F_x = ma_x \Rightarrow T - (mg)\sin 18.5° = ma_x$$

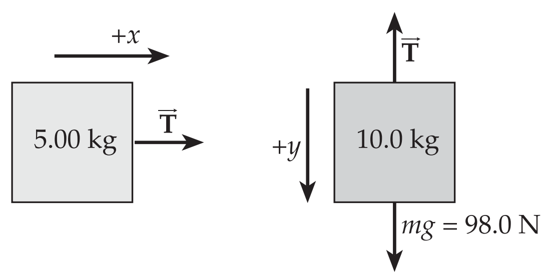
which gives

$$a_x = \frac{T}{m} - g(\sin 18.5°) = \frac{140 \text{ N}}{40.0 \text{ kg}} - (9.80 \text{ m/s}^2)\sin 18.5° = 0.390 \text{ m/s}^2$$

The velocity after moving 80.0 m up the incline is given by

$$v = \sqrt{v_0^2 + 2a_x(\Delta x)} = \sqrt{0 + 2(0.390 \text{ m/s}^2)(80.0 \text{ m})} = \boxed{7.90 \text{ m/s}}$$

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



(a) (b)

$$\Sigma F_x = ma_x \Rightarrow T = (5.00 \text{ kg})a \qquad (1)$$

Next consider the block which moves vertically. The forces on it are the tension T and its weight, 98.0 N.

$$\Sigma F_y = ma_y \Rightarrow 98.0 \text{ N} - T = (10.0 \text{ kg})a \qquad (2)$$

Note that both blocks must have the same magnitude of acceleration. Equations (1) and (2) can be solved simultaneously to give.

$$a = \boxed{6.53 \text{ m/s}^2}\text{, and } T = \boxed{32.7 \text{ N}}$$

4.31 Taking forward as the positive direction, the acceleration that the braking force gives the train is

$$a = \frac{F}{m} = \frac{-1.87 \times 10^6 \text{ N}}{5.22 \times 10^6 \text{ kg}} = -0.358 \text{ m/s}^2$$

(a) The velocity of the train at $t = 30.0$ s is then

$$v = v_0 + at = \left(90.0 \ \frac{\text{km}}{\text{h}}\right)\left(\frac{0.447 \text{ m/s}}{1.61 \text{ km/h}}\right) + \left(-0.358 \text{ m/s}^2\right)(30.0 \text{ s}) = \boxed{14.2 \text{ m/s}}$$

(b) During this time, the displacement of the train is

$$\Delta x = v_0 t + \tfrac{1}{2}at^2 = \left(90.0 \ \frac{\text{km}}{\text{h}}\right)\left(\frac{0.447 \text{ m/s}}{1.61 \text{ km/h}}\right)(30.0 \text{ s}) + \tfrac{1}{2}\left(-0.358 \text{ m/s}^2\right)(30.0 \text{ s})^2$$

or $\Delta x = \boxed{588 \text{ m}}$

4.32 (a) When the acceleration is upward, the total upward force $\boxed{T}$ must exceed the total downward force $w = mg = (1\,500 \text{ kg})\left(9.80 \text{ m/s}^2\right) = 1.47 \times 10^4 \text{ N}$

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

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

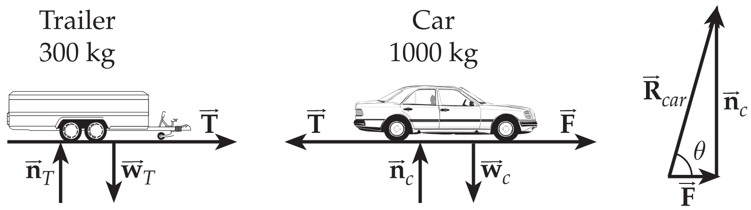
(e) $\Sigma F_y = ma_y \quad \Rightarrow \quad T = mg + ma_y = (1\,500 \text{ kg})\left(9.80 \text{ m/s}^2 + 0\right) = \boxed{1.47 \times 10^4 \text{ N}}$

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

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

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

4.33



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

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

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

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

(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), $F = T + 2.15\times 10^3\ \text{N} = +2.80\times 10^3\ \text{N}$

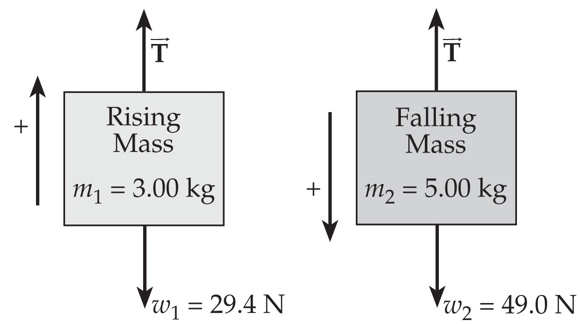
Also, $\left(\Sigma F_y\right)_{car} = n_c - w_c = m_{car}a_y = 0$, so $n_c = w_c = m_{car}g = 9.80\times 10^3\ \text{N}$

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

$$R_{car} = \sqrt{F^2 + n_c^2} = \sqrt{\left(2.80\times 10^3\ \text{N}\right)^2 + \left(9.80\times 10^3\ \text{N}\right)^2} = 1.02\times 10^4\ \text{N}$$

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

$$\boxed{1.02\times 10^4\ \text{N at } 74.1° \text{ below the horizontal and rearward}}$$



4.34 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

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

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

$$49\text{ N} - T = (5.00\text{ kg})a \qquad (2)$$

Equations (1) and (2) can be solved simultaneously to give

(a) the tension as $T = \boxed{36.8\text{ N}}$

(b) and the acceleration as $a = \boxed{2.45\text{ m/s}^2}$

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

$$\Delta y = v_{0y}t + \frac{1}{2}a_y t^2 = 0 + \frac{1}{2}(2.45\text{ m/s}^2)(1.00\text{ s})^2 = \boxed{1.23\text{ m}}$$

4.35 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

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

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

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

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

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

This exceeds the force attempting to move the system, the weight of m_2. Hence, the system remains at rest and the acceleration is $a = \boxed{0}$

(b) Once motion begins, the friction force retarding the motion is $f_k = \mu_k n_1 = \mu_k m_1 g$. This is less than the force trying to move the system, weight of m_2. Hence, the system gains speed at the rate

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

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

Applying Newton's second law:

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

and $\Sigma F_y = n - F\sin 20.0° - w = 0$, or

$$n = (300\text{ N})\sin 20.0° + 1000\text{ N} = 1.10 \times 10^3\text{ N}$$

The coefficient of friction is then $\mu_k = \dfrac{f_k}{n} = \dfrac{282\text{ N}}{1.10 \times 10^3\text{ N}} = \boxed{0.256}$

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

$$a = \frac{(F\cos 20.0° - f_k)g}{w} = \frac{[(300\ \text{N})\cos 20.0° - 230\ \text{N}](9.80\ \text{m/s}^2)}{1000\ \text{N}} = \boxed{0.509\ \text{m/s}^2}$$

4.38 (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 $f_k = -ma_x$.

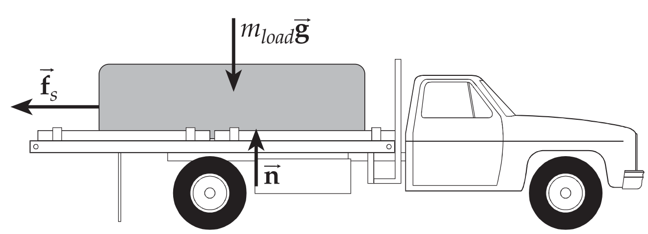
The normal force exerted on the puck by the ice is $n = mg$, so the coefficient of friction is

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

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

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

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



This single horizontal force must give the load an acceleration equal to that the truck.

Thus, $\Sigma F_x = ma_x \quad \Rightarrow \quad -\mu_s m_{load} g = m_{load} a_{truck}$

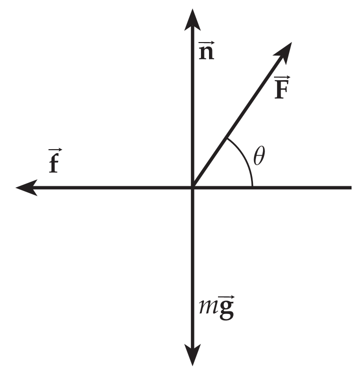
If slipping is to be avoided, the maximum allowable rearward acceleration of the truck is seen to be $a_{truck} = -\mu_s g$ and the minimum stopping distance will be

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

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

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

4.40 $m = 20.0$ kg, $F = 35.0$ N, $mg = 196$ N



(a) Since the velocity is constant,

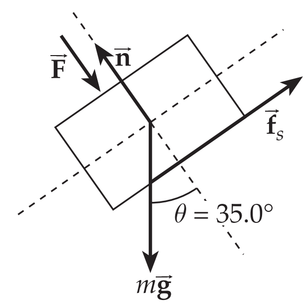
$\Sigma F_x = F\cos\theta - f = 0$, or

$$\cos\theta = \frac{f}{F} = \frac{20.0\ \text{N}}{35.0\ \text{N}} = 0.571,\ \theta = \boxed{55.2°}$$

(b) $\Sigma F_y = n + F\sin\theta - mg = 0$, so

$$n = mg - F\sin\theta = [196 - 35.0\sin(55.2°)]\ \text{N} = \boxed{167\ \text{N}}$$

4.41 The normal force acting on the crate is given by $n = F + mg\cos\theta$. The net force tending to move the crate down the incline is $mg\sin\theta - f_s$, 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 that $f_s = F_g\sin\theta$

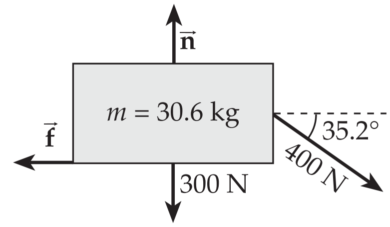


But, we also know $f_s \le \mu_s n = \mu_s(F + mg\cos\theta)$

Therefore, we may write $mg\sin\theta \le \mu_s(F + mg\cos\theta)$, or

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

4.42 In the vertical direction, we have



$$n - 300\text{ N} - (400\text{ N})\sin 35.2° = 0$$

from which, $n = 531\text{ N}$

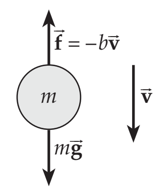
Therefore, $f = \mu_k n = (0.570)(531\text{ N}) = 302\text{ N}$

From applying the second law to the horizontal motion, we have

$$(400\text{ N})\cos 35.2° - 302\text{ N} = (30.6\text{ kg})a_x\text{, yielding } a_x = 0.798\text{ m/s}^2$$

Then, from $\Delta x = v_{0x}t + \frac{1}{2}a_x t^2$, we have $4.00\text{ m} = 0 + \frac{1}{2}(0.798\text{ m/s}^2)t^2$, which gives $t = \boxed{3.17\text{ s}}$

4.43 (a) The object will fall so that $ma = mg - bv$, or $a = \dfrac{(mg - bv)}{m}$ where the downward direction is taken as positive.

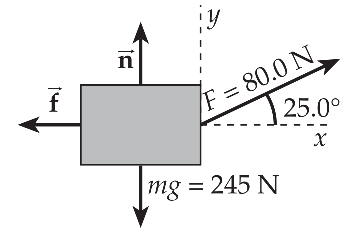


Equilibrium $(a = 0)$ is reached when

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

(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.

4.44 (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 $n = 211 \text{ N}$

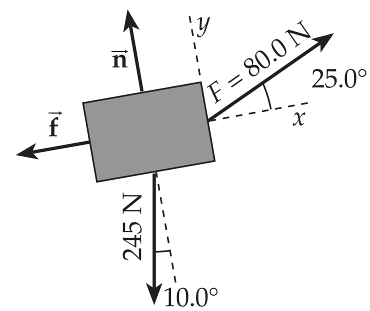
Now find the friction force, *f*, as

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

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

$$(80.0 \text{ N})\cos 25.0° - 63.4 \text{ N} = (25.0 \text{ kg})a \text{ which yields } a = \boxed{0.366 \text{ m/s}^2}$$

(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 $n = 207 \text{ N}$

The friction force is

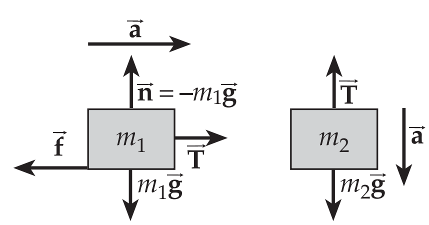
$$f = \mu_k n = 0.300(207 \text{ N}) = 62.2 \text{ N}$$

The net force parallel to the incline is

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

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

4.45 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

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

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

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

4.46 (a) The force of friction is found as $f = \mu_k n = \mu_k(mg)$
Choose the positive direction of the x-axis in the direction of motion and apply the second law. We have $-f = ma_x$, or $a_x = \dfrac{-f}{m} = -\mu_k g$

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

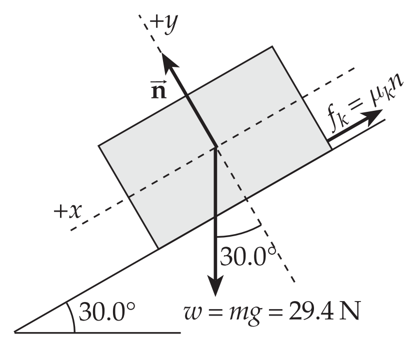
$$0 = (13.9\text{ m/s})^2 + 2(-\mu_k g)(\Delta x)\text{, or} \qquad \Delta x = \frac{(13.9\text{ m/s})^2}{2\mu_k g} \qquad (1)$$

With $\mu_k = 0.100$, this gives $\Delta x = \boxed{98.6\text{ m}}$

(b) With $\mu_k = 0.600$, Equation (1) above gives $\Delta x = \boxed{16.4\text{ m}}$

4.47 (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, the 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 $\qquad f_k = 9.37$ N

Perpendicular to the plane, we have equilibrium, so

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

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

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

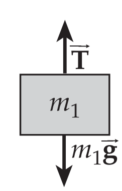
(d) Finally, $v^2 = v_0^2 + 2a_x(\Delta x)$ gives

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

4.48 (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:

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

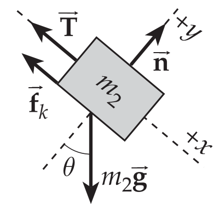
(b) Consider the free-body diagram of m_1 and apply Newton's 2nd law:



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

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

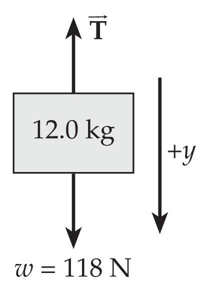
$$\Sigma F_x = ma_x \quad \Rightarrow \quad m_2 g\sin\theta - T - f_k = m_2(+a)$$

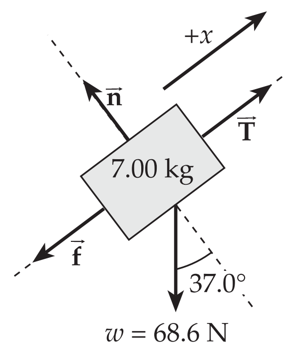
Then $$f_k = m_2(g\sin\theta - a) - T$$

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

4.49 First, taking downward as positive, apply the second law to the 12.0 kg block:





$$\Sigma F_y = 118 \text{ N} - T = (12.0 \text{ kg})a \quad (1)$$

For the 7.00 kg block, we have

$$n = (68.6 \text{ N})\cos 37.0° = 54.8 \text{ N}, \text{ and}$$

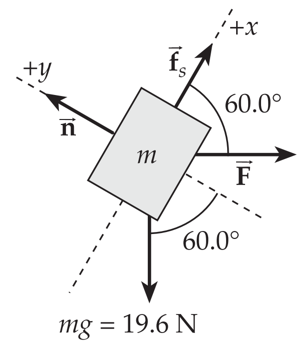
$$f = \mu_k n = (0.250)(54.8 \text{ N}) = 13.7 \text{ N}$$

Taking up the incline as the positive direction and applying the 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

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

Solving Equations (1) and (2) simultaneously yields $a = \boxed{3.30 \text{ m/s}^2}$.

4.50 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

$$\Sigma F_x = F\cos 60.0° + f_s - (19.6 \text{ N})\sin 60.0° = 0 \qquad (1)$$

and

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

For minimum F (impending motion), $f_s = (f_s)_{\text{max}} = \mu_s n = (0.300)n$ (3)

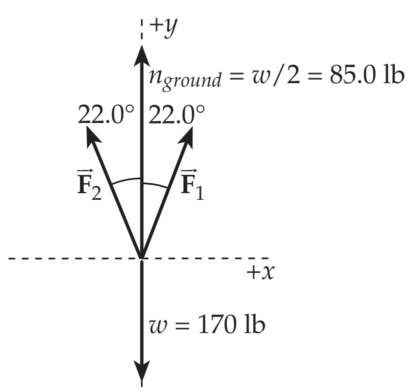
Equation (2) gives $n = 0.866F + 9.80 \text{ N}$ (4)

(a) Equation (3) becomes: $f_s = 0.260F + 2.94 \text{ N}$, so Equation (1) gives

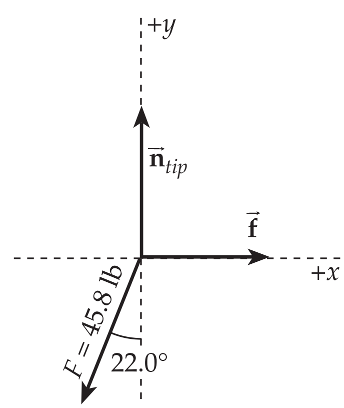
$$0.500F + 0.260F + 2.94 \text{ N} - 17.0 \text{ N} = 0\text{, or } F = \boxed{18.5 \text{ N}}$$

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

4.51



Free-Body Diagram of Person



Free-Body Diagram of Crutch Tip

From the free-body diagram of the person,

$$\Sigma F_x = F_1 \sin(22.0°) - F_2 \sin(22.0°) = 0\text{, which gives or } F_1 = F_2 = F$$

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.

$$\Sigma F_x = f - (45.8 \text{ lb})\sin 22.0° = 0 \text{, or} \qquad f = 17.2 \text{ lb}$$

$$\Sigma F_y = n_{tip} - (45.8 \text{ lb})\cos 22.0° = 0 \text{, which gives} \qquad n_{tip} = 42.5 \text{ lb}$$

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

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

4.52 (a) First, draw a free-body diagram (Fig. 1) of the top block. Since $a_y = 0$, $n_1 = 19.6 \text{ N}$ and,

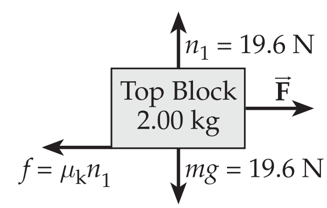


Figure 1

$$f = \mu_k n_1 = (0.300)(19.6 \text{ N}) = 5.88 \text{ N}$$

$$\Sigma F_x = ma_T \text{ gives } 10.0 \text{ N} - 5.88 \text{ N} = (2.00 \text{ kg})a_T$$

or $a_T = 2.06 \text{ m/s}^2$ (for top block)

Now draw a free-body diagram (Fig. 2) of the bottom block and observe that $\Sigma F_x = Ma_B$ gives

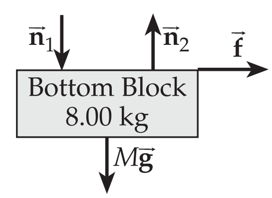


Figure 2

$$f = 5.88 \text{ N} = (8.00 \text{ kg})a_B \text{, or}$$

$a_B = 0.735 \text{ m/s}^2$. (for the bottom block)

In time t, the distance each block moves (starting from rest) is

$$d_T = \frac{1}{2}a_T t^2 = (1.03 \text{ m/s}^2)t^2 \text{, and}$$

$$d_B = \frac{1}{2}a_B t^2 = (0.368 \text{ m/s}^2)t^2$$

For the top block to reach the right edge of the bottom block, it is necessary (See Fig. 3.) that

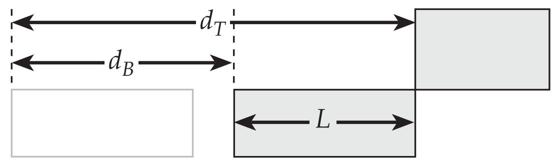


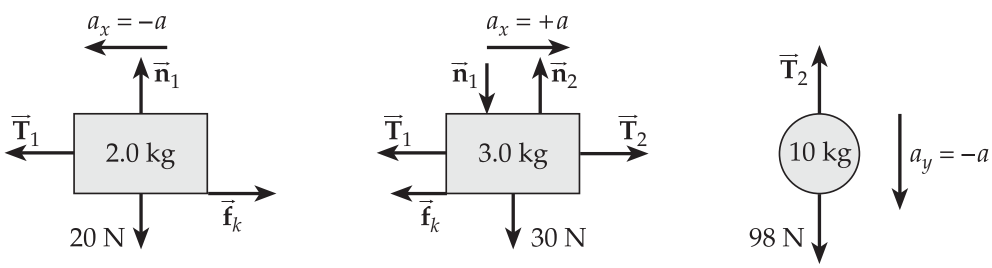
Figure 3

$d_T = d_B + L$, or

$\left(1.03\ \text{m/s}^2\right)t^2 = \left(0.368\ \text{m/s}^2\right)t^2 + 3.00\ \text{m}$ which gives $t = \boxed{2.13\ \text{s}}$

(b) From above, $d_B = \dfrac{1}{2}a_B t^2 = \left(0.368\ \text{m/s}^2\right)\left(2.13\ \text{s}\right)^2 = \boxed{1.67\ \text{m}}$

4.53 (a)



(b) For the 10-kg object:

$\Sigma F_y = ma_y \;\Rightarrow\; T_2 - 98\ \text{N} = \left(10\ \text{kg}\right)\left(-a\right)$ or $T_2 = 98\ \text{N} - \left(10\ \text{kg}\right)a$ (1)

For the 2.0-kg object: $\Sigma F_y = ma_y \Rightarrow n_1 - 20\ \text{N} = 0$ or $n_1 = 20\ \text{N}$

so $f_k = \mu_k n_1 = (0.30)(20\ \text{N}) = 6.0\ \text{N}$

Also, $\Sigma F_x = ma_x \Rightarrow 6.0\ \text{N} - T_1 = \left(2.0\ \text{kg}\right)\left(-a\right)$ or $T_1 = 6.0\ \text{N} + \left(2.0\ \text{kg}\right)a$ (2)

Finally, for the 3.0-kg object:

$\Sigma F_x = ma_x \Rightarrow T_2 - T_1 - 6.0\ \text{N} = \left(3.0\ \text{kg}\right)\left(+a\right)$ or $T_2 - T_1 = 6.0\ \text{N} + \left(3.0\ \text{kg}\right)a$ (3)

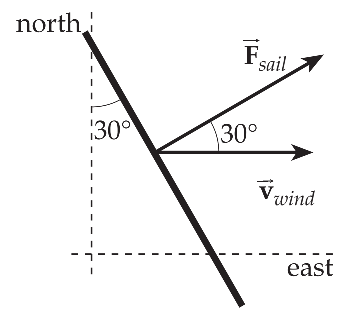
Substituting Equations (1) and (2) into Equation (3) yields:

$98\ \text{N} - \left(10\ \text{kg}\right)a - 6.0\ \text{N} - \left(2.0\ \text{kg}\right)a = 6.0\ \text{N} + \left(3.0\ \text{kg}\right)a$ or $a = \dfrac{86\ \text{N}}{15\ \text{kg}} = \boxed{5.7\ \text{m/s}^2}$

(c) Substituting the computed value for the magnitude of the acceleration into Equations (1) and (2) gives: $T_1 = 6.0\ \text{N} + \left(2.0\ \text{kg}\right)\left(5.7\ \text{m/s}^2\right) = \boxed{17\ \text{N}}$

and $T_2 = 98\ \text{N} - \left(10\ \text{kg}\right)\left(5.7\ \text{m/s}^2\right) = \boxed{41\ \text{N}}$

4.54 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.



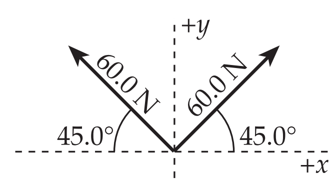
When the sail is oriented at 30° from the north-south line and the wind speed is $v_{wind} = 17$ knots, we have

$$F_{sail} = \left(550\ \frac{\text{N}}{\text{m/s}}\right)\left|\vec{\mathbf{v}}_{wind}\right|_{\perp} = \left(550\ \frac{\text{N}}{\text{m/s}}\right)\left[(17\text{ knots})\left(\frac{0.514\ \text{m/s}}{1\text{ knot}}\right)\cos 30°\right] = 4.2\times10^{3}\ \text{N}$$

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

$$a = \frac{\left|\vec{\mathbf{F}}_{sail}\right|_{north}}{m} = \frac{(4.2\times10^{3}\ \text{N})\sin 30°}{800\ \text{kg}} = \boxed{2.6\ \text{m/s}^2}$$

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



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

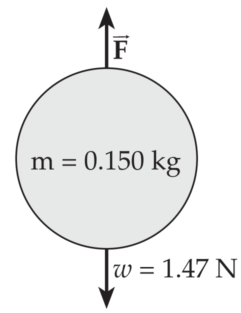
The resultant y component is:

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

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

(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, $w = \boxed{84.9\ \text{N}}$

4.56 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

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

4.57 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, the 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

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

4.58 (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 required coefficient of friction is $\mu_s = \dfrac{f_s}{n} = \dfrac{50.0\ \text{N}}{100\ \text{N}} = \boxed{0.500}$

(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 $w = T = \boxed{25.0\ \text{N}}$

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

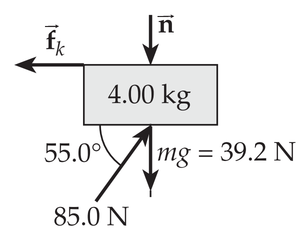
(b) The maximum acceleration the truck can have before the box slides is found by considering the maximum static friction force the truck bed can exert on the box:

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

Thus, from the second law,

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

4.60 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 $n = 30.4\ \text{N}$

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

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

4.61 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

$$a = \frac{F}{m} = \frac{mg\sin\theta}{m} = g\sin\theta = \left(9.80\ \text{m/s}^2\right)\sin 35.0° = 5.62\ \text{m/s}^2$$

directed down the incline.

(a) The time for the sled projected up the incline to come to rest is given by

$$t = \frac{v - v_0}{a} = \frac{0 - 5.00\ \text{m/s}}{-5.62\ \text{m/s}^2} = 0.890\ \text{s}$$

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, $t = 0.890\ \text{s}$. 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 $\Delta s = v_0 t + \frac{1}{2}at^2$ as

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

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

4.62 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 m_1: $m_1 a = T_1 - m_1 g$ (1)

for m_2: $m_2 a = T_2 + m_2 g - T_1$ (2)

for m_3: $m_3 a = m_3 g - T_2$ (3)

Adding these equations yields $(m_1 + m_2 + m_3)a = (-m_1 + m_2 + m_3)g$, so

$$a = \left(\frac{-m_1 + m_2 + m_3}{m_1 + m_2 + m_3}\right)g = \left(\frac{2.00\ \text{kg}}{12.0\ \text{kg}}\right)(9.80\ \text{m/s}^2) = \boxed{1.63\ \text{m/s}^2}$$

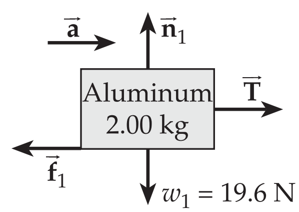
(b) From Equation (1), $T_1 = m_1(a+g) = (5.00\ \text{kg})(11.4\ \text{m/s}^2) = \boxed{57.2\ \text{N}}$, and

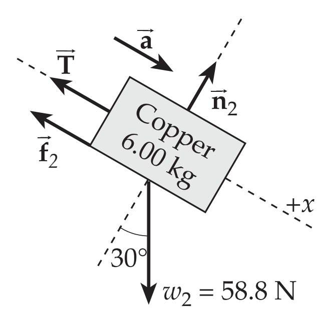
from Equation (3), $T_2 = m_3(g-a) = (3.00\ \text{kg})(8.17\ \text{m/s}^2) = \boxed{24.5\ \text{N}}$

4.63 (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, $n_1 = w_1$ 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:

$\Sigma F_x = ma_x \Rightarrow T - f_1 = m(+a)$ or $T = f_1 + ma$

giving $T = 9.21\ \text{N} + (2.00\ \text{kg})a$ (1)

For the copper block:

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

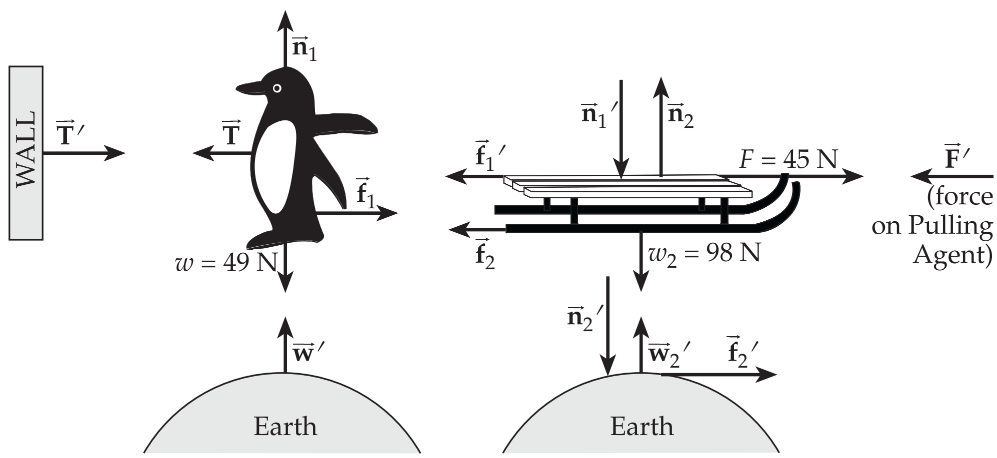
or $11.1\ \text{N} - T = (6.00\ \text{kg})a$ (2)

Substituting Equation (1) into Equation (2) gives

$$11.1\ \text{N} - 9.21\ \text{N} - (2.00\ \text{kg})a = (6.00\ \text{kg})a \text{ or } a = \frac{1.86\ \text{N}}{8.00\ \text{kg}} = \boxed{0.232\ \text{m/s}^2}$$

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

4.64 (a) Force diagrams for penguin and sled are shown. The primed forces are reaction forces for the corresponding unprimed forces.



(b) The weight of the penguin is 49 N, and hence the normal force exerted on him by the sled, n_1, is also 49 N. Thus, the friction force acting on the penguin is:
$f_1 = \mu_k n_1 = 0.20(49\text{ N}) = 9.8\text{ N}$

Since the penguin is in equilibrium, the tension in the cord attached to the wall and the friction force f_1 must be equal: $T = \boxed{9.8\text{ N}}$

(c) The normal force exerted on the sled by the Earth is the weight of the penguin (49 N) plus the weight of the sled (98 N). Thus, the net normal force, n_2 equals 147 N, and the friction force between sled and ground is:
$f_2 = \mu_k n_2 = 0.20(147\text{ N}) = 29.4\text{ N}$

Applying the second law to the horizontal motion of the sled gives:

$$45\text{ N} - f_1' - f_2 = (10\text{ kg})a \qquad \text{or} \qquad a = \boxed{0.58\ \text{m/s}^2}$$

4.65 Figure 1 is a free-body diagram for the system consisting of both blocks. The friction forces are $f_1 = \mu_k n_1 = \mu_k(m_1 g)$ and $f_2 = \mu_k(m_2 g)$. 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

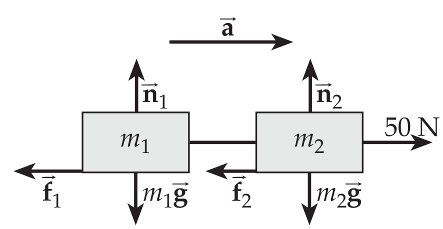


Figure 1

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

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

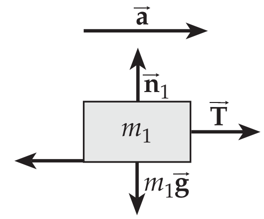


Figure 2

$$T = m_1\left(a + \mu_k g\right) \qquad (2)$$

(a) 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 $T = (10\text{ kg})\left(1.7\text{ m/s}^2 + 0\right) = \boxed{17\text{ N}}$

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

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

while Equation (2) gives the tension as

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

4.66 Before he enters the water, the diver is in free-fall with an acceleration of 9.80 m/s^2 downward. Taking downward as the positive direction, his velocity when he reaches the water is given by

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

His average acceleration during the 2.00 s after he enters the water is

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

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

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

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

4.67 We shall choose the positive direction to be to the right and call the forces exerted by each of the people $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$. Thus, when pulling in the same direction, Newton's second law becomes

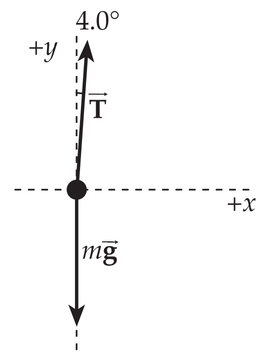
$$F_1 + F_2 = (200\ \text{kg})(1.52\ \text{m/s}^2)\text{, or} \qquad F_1 + F_2 = 304\ \text{N} \qquad (1)$$

When pulling in opposite directions,

$$F_1 - F_2 = (200\ \text{kg})(-0.518\ \text{m/s}^2)\text{, or} \qquad F_1 - F_2 = -104\ \text{N} \qquad (2)$$

Solving simultaneously, we find: $F_1 = \boxed{100\ \text{N}}$, and $F_2 = \boxed{204\ \text{N}}$

4.68 In the vertical direction, we have



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

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 The magnitude of the acceleration is $a = 2.00\ \text{m/s}^2$ for all three blocks and applying Newton's second law to the 10.0-kg block gives

$$(10.0\ \text{kg})(9.80\ \text{m/s}^2) - T_1 = (10.0\ \text{kg})(2.00\ \text{m/s}^2)\text{, or } T_1 = 78.0\ \text{N}$$

Applying the second law to the 5.00-kg block gives:

$$T_1 - T_2 - \mu_k\left[(5.00\ \text{kg})(9.80\ \text{m/s}^2)\right] = (5.00\ \text{kg})(2.00\ \text{m/s}^2)$$

With $T_1 = 78.0\ \text{N}$, this simplifies to: $T_2 = 68.0\ \text{N-}(49.0\ \text{N})\mu_k$ (1)

For the 3.00-kg block, the second law gives $T_2 - \mu_k n - [mg\sin 25.0°] = ma$

With $m = 3.00$ kg, $a = 2.00\ \text{m/s}^2$, $g = 9.80\ \text{m/s}^2$, and $n = mg\cos 25.0°$, this reduces to:

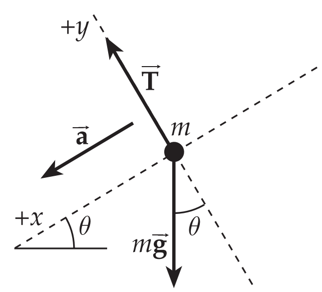
$$T_2 - (26.6\ \text{N})\mu_k = 18.4\ \text{N} \qquad (2)$$

Solving Equations (1) and (2) simultaneously, and using the value of T_1 from above, we find that

(a) $T_1 = \boxed{78.0\ \text{N}}$, $T_2 = \boxed{35.9\ \text{N}}$, and (b) $\mu_k = \boxed{0.656}$

4.70 The scale simply reads the magnitude of the normal force exerted on the student by the seat. The seat is parallel to the track, and hence inclined at 30.0° to the horizontal. Thus, the magnitude of this normal force and the scale reading is
$n = mg\cos\theta = (200\ \text{lb})\cos 30.0° = \boxed{173\ \text{lb}}$

4.71 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) $\Sigma F_x = mg\sin\theta = ma_x$, $\theta = \sin^{-1}\left(\frac{a_x}{g}\right) = \sin^{-1}\left(\frac{5.00\ \text{m/s}^2}{9.80\ \text{m/s}^2}\right) = \boxed{30.7°}$

and

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

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

4.72 Taking the downward direction as positive, applying the 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, $v_y^2 = v_{0y}^2 + 2a_y(\Delta y)$ gives the velocity just before hitting the net as

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

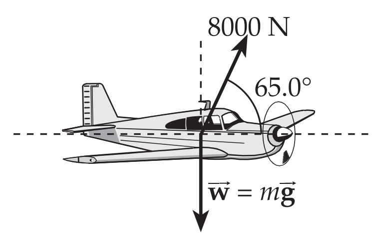
4.73 The acceleration the car has as it is coming to a stop is

$$a = \frac{v^2 - v_0^2}{2(\Delta x)} = \frac{0 - (35\ \text{m/s})^2}{2(1000\ \text{m})} = -0.61\ \text{m/s}^2$$

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

$$|F| = m|a| = \left(\frac{w}{g}\right)|a| = \left(\frac{8800\ \text{N}}{9.80\ \text{m/s}^2}\right)(0.61\ \text{m/s}^2) = \boxed{5.5 \times 10^2\ \text{N}}$$

4.74 (a) In the vertical direction, we have



$$\Sigma F_y = (8000\ \text{N})\sin 65.0° - w = ma_y = 0$$

so $w = (8000\ \text{N})\sin 65.0° = \boxed{7.25 \times 10^3\ \text{N}}$

(b) Along the horizontal, the second law yields

$$\Sigma F_x = (8000\ \text{N})\cos 65.0° = ma_x = \left(\frac{w}{g}\right)a_x\text{, or}$$

$$a_x = \frac{g\left[(8000\ \text{N})\cos 65.0°\right]}{w} = \frac{(9.80\ \text{m/s}^2)(8000\ \text{N})\cos 65.0°}{7.25 \times 10^3\ \text{N}} = \boxed{4.57\ \text{m/s}^2}$$

4.75 First, we will compute the needed accelerations:

(1) Before it starts to move: $a_y = 0$

(2) During the first 0.80 s: $a_y = \dfrac{v_y - v_{0y}}{t} = \dfrac{1.2\ \text{m/s} - 0}{0.80\ \text{s}} = 1.5\ \text{m/s}^2$

(3) While moving at constant velocity: $a_y = 0$

(4) During the last 1.5 s: $a_y = \dfrac{v_y - v_{0y}}{t} = \dfrac{0 - 1.2\ \text{m/s}}{1.5\ \text{s}} = -0.80\ \text{m/s}^2$

Applying Newton's second law to the vertical motion of the man gives:

$$\Sigma F_y = n - mg = ma_y \text{, or } n = m\left(g + a_y\right)$$

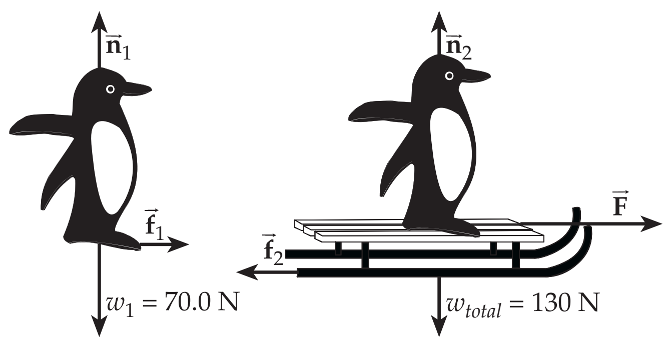
(a) When $a_y = 0$, $n = (72\ \text{kg})\left(9.80\ \text{m/s}^2 + 0\right) = \boxed{7.1 \times 10^2\ \text{N}}$

(b) When $a_y = 1.5\ \text{m/s}^2$, $n = \boxed{8.1 \times 10^2\ \text{N}}$

(c) When $a_y = 0$, $n = \boxed{7.1 \times 10^2\ \text{N}}$

(d) When $a_y = -0.80\ \text{m/s}^2$, $n = \boxed{6.5 \times 10^2\ \text{N}}$

4.76 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

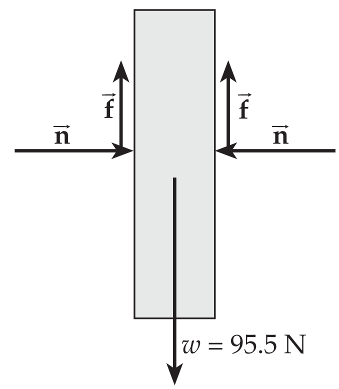
$$a_{\max} = \frac{\left(f_1\right)_{\max}}{m_1} = \frac{\mu_s\left(m_1 g\right)}{m_1} = \mu_s g = (0.700)\left(9.80\ \text{m/s}^2\right) = 6.86\ \text{m/s}^2$$

Since the penguin does not slip on the sled, the combined system must have the same acceleration as the penguin. Hence, applying the second law to the combined system gives $\Sigma F_x = F - f_2 = m_{total}\, a_{\max}$, or

$$F = f_2 + m_{total}\, a_{\max} = \mu_k\left(w_{total}\right) + \left(\frac{w_{total}}{g}\right) a_{\max}$$

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

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 $f = \left(f_s\right)_{max} = \mu_s n$



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 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:

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

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

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

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

The elapsed time when this occurs is

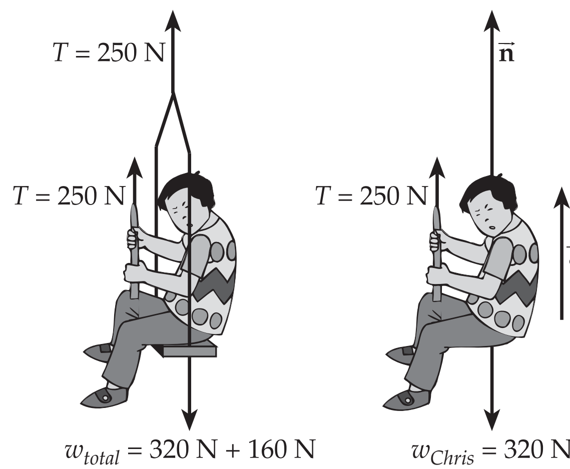
$$t = \sqrt{\frac{0.300\text{ m}}{(1.50 - 0.250)\ \text{m/s}^2}} = 0.490\text{s}$$

At this time, the mug has moved a distance of

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

4.79 (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 the second law as

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

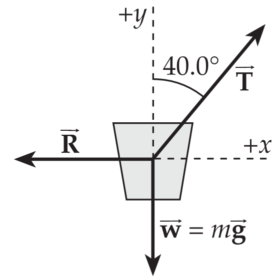
Thus, $a_y = \dfrac{500\text{ N} - 480\text{ N}}{49.0\text{ kg}} = +0.408\ \text{m/s}^2$ or $\boxed{0.408\ \text{m/s}^2\ \text{upward}}$

(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

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

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

4.80 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:

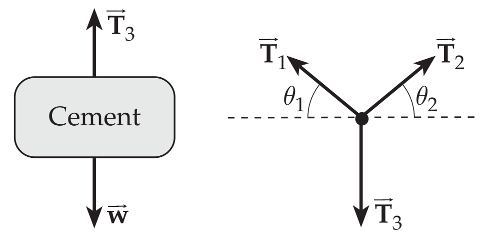


$$\Sigma F_y = T\cos 40.0° - mg = 0, \text{ or } T = \frac{mg}{\cos 40.0°}$$

Also, $\Sigma F_x = T\sin 40.0° - R = 0$, or $R = T\sin 40.0°$

Thus, $R = mg\tan 40.0° = (620\text{ kg})(9.80\text{ m/s}^2)\tan 40.0° = \boxed{5.10\times 10^3\text{ N}}$

4.81 Consider two free-body diagrams, one of the cement bag and one of the junction of the three wires as given at the right.



Using the first diagram:

$$\Sigma F_y = 0 \Rightarrow T_3 = w \qquad (1)$$

Then, using the second free-body diagram:

$$\Sigma F_x = 0 \Rightarrow T_2\cos\theta_2 - T_1\cos\theta_1 = 0 \quad \text{or} \quad T_2 = \frac{T_1\cos\theta_1}{\cos\theta_2} \qquad (2)$$

and $$\Sigma F_y = 0 \Rightarrow T_2\sin\theta_2 + T_1\sin\theta_1 - T_3 = 0 \quad \text{or} \quad T_2\sin\theta_2 + T_1\sin\theta_1 = T_3 \qquad (3)$$

(a) Substituting Equations (1) and (2) into Equation (3) yields

$$T_1(\sin\theta_2\cos\theta_1 + \sin\theta_1\cos\theta_2) = w\cos\theta_2$$

Making use of the trigonometric identity $\sin(\theta_1+\theta_2) = \sin\theta_2\cos\theta_1 + \sin\theta_1\cos\theta_2$, the above expression reduces to: $\boxed{T_1 = \dfrac{w\cos\theta_2}{\sin(\theta_1+\theta_2)}}$

(b) If $w = 325$ N, while $\theta_1 = 10.0°$ and $\theta_2 = 25.0°$, we find that:

$$T_1 = \frac{w\cos\theta_2}{\sin(\theta_1+\theta_2)} = \frac{(325\text{ N})\cos 25.0°}{\sin(10.0°+25.0°)} = \boxed{514\text{ N}}$$

$$T_2 = \frac{T_1\cos\theta_1}{\cos\theta_2} = \frac{(514\text{ N})\cos 10.0°}{\cos 25.0°} = \boxed{558\text{ N}}$$

and $T_3 = w = \boxed{325}$