CHAPTER 4: Dynamics: Newton's Laws of Motion

Answers to Questions

1. The child tends to remain at rest (Newton's 1st Law), unless a force acts on her. The force is applied to the wagon, not the child, and so the wagon accelerates out from under the child, making it look like the child falls backwards relative to the wagon. If the child is standing in the wagon, the force of friction between the child and the bottom of the wagon will produce an acceleration of the feet, pulling the feet out from under the child, also making the child fall backwards.

2. (*a*) Mary sees the box stay stationary with respect to the ground. There is no horizontal force on the box since the truck bed is smooth, and so the box cannot accelerate. Thus Mary would describe the motion of the box in terms of Newton's 1st law – there is no force on the box, so it does not accelerate.
   (*b*) Chris, from his non-inertial reference frame, would say something about the box being "thrown" backwards in the truck, and perhaps use Newton's 2nd law to describe the effects of that force. But the source of that force would be impossible to specify.

3. If the acceleration of an object is zero, then by Newton's second law, the *net* force must be zero. There can be forces acting on the object as long as the vector sum of the forces is zero.

4. If only once force acts on the object, then the net force cannot be zero. Thus the object cannot have zero acceleration, by Newton's second law. The object can have zero velocity for an instant. For example, an object thrown straight up under the influence of gravity has a velocity of zero at the top of its path, but has a non-zero net force and non-zero acceleration throughout the entire flight.

5. (*a*) A force is needed to bounce the ball back up, because the ball changes direction, and so accelerates. If the ball accelerates, there must be a force.
   (*b*) The pavement exerts the force on the golf ball.

6. When you try to walk east, you push on the ground (or on the log in this case) with a westward force. When you push westward on the massive Earth, the Earth moves imperceptibly, but by Newton's 3rd law there is an eastward force on you, which propels you forward. When walking on the log, the relatively light and unrestricted log is free to move, and so when you push it westward, it moves westward as you move eastward.

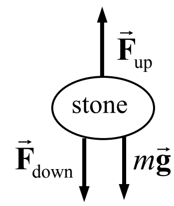
7. By Newton's 3rd law, the desk or wall exerts a force on your foot equal in magnitude to the force with which you hit the desk or wall. If you hit the desk or wall with a large force, then there will be a large force on your foot, causing pain. Only a force <u>on</u> your foot causes pain.

8. (*a*) When you are running, the stopping force is a force of friction between your feet and the ground. You push forward with your feet on the ground, and thus the ground pushes backwards on you, slowing your speed.
   (*b*) A fast person can run about 10 meters per second, perhaps takes a distance of 5 meters over which to stop. Those 5 meters would be about 5 strides, of 1 meter each. The acceleration can be found from Eq. 2-11c.

$$v^2 - v_0^2 = 2a(x - x_0) \quad \rightarrow \quad a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - (10\,\text{m/s})^2}{10\text{ m}} = -10\,\text{m/s}^2$$

9. When giving a sharp pull, the key is the suddenness of the application of the force. When a large, sudden force is applied to the bottom string, the bottom string will have a large tension in it. Because of the stone's inertia, the upper string does not immediately experience the large force. The bottom string must have more tension in it, and will break first.

If a slow and steady pull is applied, the tension in the bottom string increases. We approximate that condition as considering the stone to be in equilibrium until the string breaks. The free-body diagram for the stone would look like this diagram. While the stone is in equilibrium, Newton's 2nd law states that $F_{up} = F_{down} + mg$. Thus the tension in the upper string is going to be larger than the tension in the lower string because of the weight of the stone, and so the upper string will break first.



10. The acceleration of both rocks is found by dividing their weight (the force of gravity on them) by their mass. The 2-kg rock has a force of gravity on it that is twice as great as the force of gravity on the 1-kg rock, but also twice as great a mass as the 1-kg rock, so the acceleration is the same for both.

11. Only the pounds reading would be correct. The spring scale works on the fact that a certain **force** (the weight of the object being weighed) will stretch the spring a certain distance. That distance is proportional to the product of the mass and the acceleration due to gravity. Since the acceleration due to gravity is smaller by a factor of 6 on the moon, the weight of the object is smaller by a factor of 6, and the spring will be pulled to only one-sixth of the distance that it was pulled on the Earth. The mass itself doesn't change when moving to the Moon, and so a mass reading on the Moon would be incorrect.

12. When you pull the rope at an angle, only the horizontal component of the pulling force will be accelerating the box across the table. This is a smaller horizontal force than originally used, and so the horizontal acceleration of the box will decrease.

13. Let us find the acceleration of the Earth, assuming the mass of the freely falling object is $m = 1$ kg. If the mass of the Earth is M, then the acceleration of the Earth would be found using Newton's 3rd law and Newton's 2nd law.

$$F_{\text{Earth}} = F_{\text{object}} \quad \rightarrow \quad Ma_{\text{Earth}} = mg \quad \rightarrow \quad a_{\text{Earth}} = g\, m/M$$

Since the Earth has a mass that is on the order of 10^{25} kg, then the acceleration of the Earth is on the order of $10^{-25}\,g$, or about $10^{-24}\ \text{m/s}^2$. This tiny acceleration is undetectable.

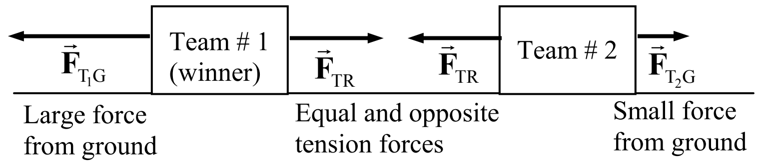
14. (*a*) To lift the object on the Earth requires a force the same size as its weight on Earth, $F_{\text{Earth}} = mg_{\text{Earth}} = 98\ \text{N}$. To lift the object on the Moon requires a force the same size as its weight on the Moon, $F_{\text{Moon}} = mg_{\text{Moon}} = mg_{\text{Moon}}/6 = 16\ \text{N}$.

(*b*) The horizontal accelerating force would be the same in each case, because the mass of the object is the same on both the Earth and the Moon, and both objects would have the same acceleration to throw them with the same speed. So by Newton's second law, the forces would have to be the same.

15. In a tug of war, the team that pushes hardest against the ground wins. It is true that both teams have the same force on them due to the tension in the rope. But the winning team pushes harder against the ground and thus the ground pushes harder on the winning team, making a net unbalanced force.

The free body diagram below illustrates this. The forces are $\vec{\mathbf{F}}_{T_1G}$, the force on team 1 from the ground, $\vec{\mathbf{F}}_{T_2G}$, the force on team 2 from the ground, and $\vec{\mathbf{F}}_{TR}$, the force on each team from the rope.

Thus the <u>net</u> force on the winning team $\left(\vec{\mathbf{F}}_{T_1G} - \vec{\mathbf{F}}_{TR}\right)$ is in the winning direction.



16. (*a*) The magnitude is 40 N.
    (*b*) The direction is downward.
    (*c*) It is exerted on the person.
    (*d*) It is exerted by the bag of groceries.

$\boxed{17.}$ If you are at rest, the net force on you is zero. Hence the ground exerts a force on you exactly equal to your weight. The two forces acting on you sum to zero, and so you don't accelerate. If you squat down and then push with a larger force against the ground, the ground then pushes back on you with a larger force by Newton's third law, and you <u>can</u> then rise into the air.

$\boxed{18.}$ In a whiplash situation, the car is violently pushed forward. Since the victim's back is against the seat of the car, the back moves forward with the car. But the head has no direct horizontal force to push it, and so it "lags behind". The victim's body is literally pushed forward, out from under their head – the head is not thrown backwards. The neck muscles must eventually pull the head forward, and that causes the whiplash. To avoid this, use the car's headrests.

$\boxed{19.}$ The truck bed exerts a force of static friction on the crate, causing the crate to accelerate.

20. On the way up, there are two forces on the block that are parallel to each other causing the deceleration – the component of weight parallel to the plane, and the force of friction on the block. Since the forces are parallel to each other, both pointing down the plane, they add, causing a larger magnitude force and a larger acceleration. On the way down, those same two forces are opposite of each other, because the force of friction is now directed up the plane. With these two forces being opposite of each other, their net force is smaller, and so the acceleration is smaller.

21. Assume your weight is W. If you weighed yourself on an inclined plane that is inclined at angle θ, the bathroom scale would read the magnitude of the normal force between you and the plane, which would be $W\cos\theta$.

Solutions to Problems

1. Use Newton's second law to calculate the force.

$$\sum F = ma = (60.0\text{ kg})\left(1.25\text{ m/s}^2\right) = \boxed{75.0\text{ N}}$$

2. Use Newton's second law to calculate the mass.

$$\sum F = ma \quad\rightarrow\quad m = \frac{\sum F}{a} = \frac{265\text{ N}}{2.30\text{ m/s}^2} = \boxed{115\text{ kg}}$$

3. Use Newton's second law to calculate the tension.

$$\sum F = F_{\mathrm{T}} = ma = (960\ \mathrm{kg})(1.20\ \mathrm{m/s^2}) = \boxed{1.15\times10^3\ \mathrm{N}}$$

4. In all cases, $W = mg$, where g changes with location.

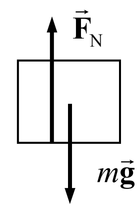
(*a*) $W_{\mathrm{Earth}} = mg_{\mathrm{Earth}} = (76\ \mathrm{kg})(9.8\,\mathrm{m/s^2}) = \boxed{7.4\times10^2\ \mathrm{N}}$

(*b*) $W_{\mathrm{Moon}} = mg_{\mathrm{Moon}} = (76\ \mathrm{kg})(1.7\,\mathrm{m/s^2}) = \boxed{1.3\times10^2\ \mathrm{N}}$

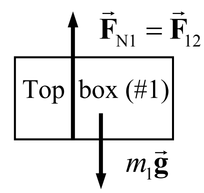
(*c*) $W_{\mathrm{Mars}} = mg_{\mathrm{Mars}} = (76\ \mathrm{kg})(3.7\,\mathrm{m/s^2}) = \boxed{2.8\times10^2\ \mathrm{N}}$

(*d*) $W_{\mathrm{Space}} = mg_{\mathrm{Space}} = (76\ \mathrm{kg})(0\,\mathrm{m/s^2}) = \boxed{0\ \mathrm{N}}$

5. (*a*) The 20.0 kg box resting on the table has the free-body diagram shown. Its weight is $mg = (20.0\ \mathrm{kg})(9.80\,\mathrm{m/s^2}) = \boxed{196\ \mathrm{N}}$. Since the box is at rest, the net force on the box must be 0, and so the normal force must also be $\boxed{196\ \mathrm{N}}$.



(*b*) Free-body diagrams are shown for both boxes. $\vec{\mathbf{F}}_{12}$ is the force on box 1 (the top box) due to box 2 (the bottom box), and is the normal force on box 1. $\vec{\mathbf{F}}_{21}$ is the force on box 2 due to box 1, and has the same magnitude as $\vec{\mathbf{F}}_{12}$ by Newton's 3rd law. $\vec{\mathbf{F}}_{\mathrm{N2}}$ is the force of the table on box 2. That is the normal force on box 2. Since both boxes are at rest, the net force on each box must be 0. Write Newton's 2nd law in the vertical direction for each box, taking the upward direction to be positive.

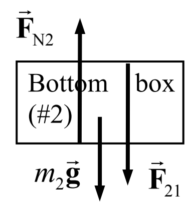


$$\sum F_1 = F_{\mathrm{N1}} - m_1 g = 0$$

$$F_{\mathrm{N1}} = m_1 g = (10.0\,\mathrm{kg})(9.80\,\mathrm{m/s^2}) = \boxed{98.0\ \mathrm{N}} = F_{12} = F_{21}$$

$$\sum F_2 = F_{\mathrm{N2}} - F_{21} - m_2 g = 0$$

$$F_{\mathrm{N2}} = F_{21} + m_2 g = 98.0\ \mathrm{N} + (20.0\,\mathrm{kg})(9.80\,\mathrm{m/s^2}) = \boxed{294\ \mathrm{N}}$$



6. Find the average acceleration from Eq. 2-2. The average force on the car is found from Newton's second law.

$$v = 0 \quad v_0 = (95\,\mathrm{km/h})\left(\frac{0.278\,\mathrm{m/s}}{1\,\mathrm{km/h}}\right) = 26.4\,\mathrm{m/s} \quad a_{avg} = \frac{v - v_0}{t} = \frac{0 - 26.4\,\mathrm{m/s}}{8.0\ \mathrm{s}} = -3.30\ \mathrm{m/s^2}$$

$$F_{avg} = ma_{avg} = (1100\ \mathrm{kg})(-3.3\ \mathrm{m/s^2}) = \boxed{-3.6\times10^3\ \mathrm{N}}$$

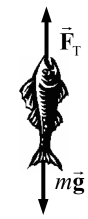
The negative sign indicates the direction of the force, in the opposite direction to the initial velocity.

7. The average force on the pellet is its mass times its average acceleration. The average acceleration is found from Eq. 2-11c. For the pellet, $v_0 = 0$, $v = 125\,\mathrm{m/s}$, and $x - x_0 = 0.800\ \mathrm{m}$.

$$a_{avg} = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(125\,\mathrm{m/s})^2 - 0}{2(0.800\ \mathrm{m})} = 9770\ \mathrm{m/s^2}$$

$$F_{avg} = ma_{avg} = (7.00\times10^{-3}\ \mathrm{kg})(9770\ \mathrm{m/s^2}) = \boxed{68.4\ \mathrm{N}}$$

8. We assume that the fishline is pulling vertically on the fish, and that the fish is not jerking the line. A free-body diagram for the fish is shown. Write Newton's 2nd law for the fish in the vertical direction, assuming that up is positive. The tension is at its maximum.



$$\sum F = F_T - mg = ma \quad \rightarrow \quad F_T = m(g+a) \quad \rightarrow$$

$$m = \frac{F_T}{g+a} = \frac{22\text{ N}}{9.8\,\text{m/s}^2 + 2.5\,\text{m/s}^2} = \boxed{1.8\text{ kg}}$$

Thus a mass of 1.8 kg is the maximum that the fishline will support with the given acceleration. Since the line broke, the fish's mass must be greater than 1.8 kg (about 4 lbs).

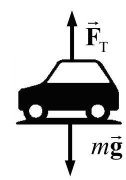
9. The problem asks for the average force on the glove, which in a direct calculation would require knowledge about the mass of the glove and the acceleration of the glove. But no information about the glove is given. By Newton's 3rd law, the force exerted by the ball on the glove is equal and opposite to the force exerted by the glove on the ball. So calculate the average force on the ball, and then take the opposite of that result to find the average force on the glove. The average force on the ball is its mass times its average acceleration. Use Eq. 2-11c to find the acceleration of the ball, with $v = 0$, $v_0 = 35.0\,\text{m/s}$, and $x - x_0 = 0.110\text{ m}$. The initial direction of the ball is the positive direction.

$$a_{avg} = \frac{v^2 - v_0^2}{2(x-x_0)} = \frac{0-(35.0\,\text{m/s})^2}{2(0.110\text{ m})} = -5568\ \text{m/s}^2$$

$$F_{avg} = ma_{avg} = (0.140\text{ kg})(-5568\ \text{m/s}^2) = \boxed{-7.80\times10^2\,\text{N}}$$

Thus the average force on the glove was 780 N, in the direction of the initial velocity of the ball.

$\boxed{10.}$ Choose up to be the positive direction. Write Newton's 2nd law for the vertical direction, and solve for the tension force.



$$\sum F = F_T - mg = ma \quad \rightarrow F_T = m(g+a)$$

$$F_T = (1200\text{ kg})(9.80\,\text{m/s}^2 + 0.80\,\text{m/s}^2) = \boxed{1.3\times10^4\,\text{N}}$$

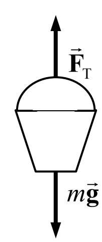
11. Use Eq. 2-11b with $v_0 = 0$ to find the acceleration.

$$x - x_0 = v_0 t + \tfrac{1}{2}at^2 \quad \rightarrow \quad a = \frac{2(x-x_0)}{t^2} = \frac{2(402\text{ m})}{(6.40\text{ s})^2} = 19.6\,\text{m/s}^2\left(\frac{1\text{ "}g\text{"}}{9.80\,\text{m/s}^2}\right) = \boxed{2.00\ g\text{'s}}$$

The accelerating force is found by Newton's 2nd law.

$$F = ma = (485\text{ kg})(19.6\,\text{m/s}^2) = \boxed{9.51\times10^3\,\text{N}}$$

12. Choose up to be the positive direction. Write Newton's 2nd law for the vertical direction, and solve for the acceleration.

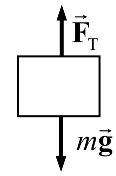


$$\sum F = F_T - mg = ma$$

$$a = \frac{F_T - mg}{m} = \frac{163\text{ N} - (12.0\text{ kg})(9.80\,\text{m/s}^2)}{12.0\text{ kg}} = \boxed{3.8\,\text{m/s}^2}$$

Since the acceleration is positive, the bucket has an $\boxed{\text{upward}}$ acceleration.

13. In both cases, a free-body diagram for the elevator would look like the adjacent diagram. Choose up to be the positive direction. To find the MAXIMUM tension, assume that the acceleration is up. Write Newton's 2nd law for the elevator.



$$\sum F = ma = F_T - mg \quad \rightarrow$$

$$F_T = ma + mg = m(a+g) = m(0.0680g + g) = (4850\ \text{kg})(1.0680)(9.80\ \text{m/s}^2)$$

$$= \boxed{5.08 \times 10^4\ \text{N}}$$

To find the MINIMUM tension, assume that the acceleration is down. Then Newton's 2nd law for the elevator becomes

$$\sum F = ma = F_T - mg \quad \rightarrow \quad F_T = ma + mg = m(a+g) = m(-0.0680g + g)$$

$$= (4850\ \text{kg})(0.9320)(9.80\ \text{m/s}^2) = \boxed{4.43 \times 10^4\ \text{N}}$$

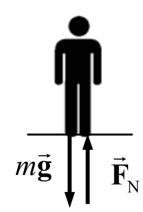
14. If the thief were to hang motionless on the sheets, or descend at a constant speed, the sheets would not support him, because they would have to support the full 75 kg. But if he descends with an acceleration, the sheets will not have to support the total mass. A free-body diagram of the thief in descent is shown. If the sheets can support a mass of 58 kg, then the tension force that the sheets can exert is $F_T = (58\ \text{kg})(9.8\ \text{m/s}^2) = 570\ \text{N}$.
Assume that is the tension in the sheets. Then write Newton's 2nd law for the thief, taking the upward direction to be positive.

$$\sum F = F_T - mg = ma \quad \rightarrow \quad a = \frac{F_T - mg}{m} = \frac{570\ \text{N} - (75\ \text{kg})(9.80\ \text{m/s}^2)}{75\ \text{kg}} = -2.2\ \text{m/s}^2$$

The negative sign shows that the acceleration is downward.

If the thief descends with an acceleration of 2.2 m/s^2 or greater, the sheets will support his descent.

15. There will be two forces on the person – their weight, and the normal force of the scales pushing up on the person. A free-body diagram for the person is shown. Choose up to be the positive direction, and use Newton's 2nd law to find the acceleration.

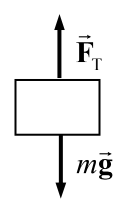


$$\sum F = F_N - mg = ma \quad \rightarrow \quad 0.75mg - mg = ma \quad \rightarrow$$

$$a = -0.25g = -0.25(9.8\ \text{m/s}^2) = \boxed{-2.5\ \text{m/s}^2}$$

Due to the sign of the result, the direction of the acceleration is $\boxed{\text{down}}$. Thus the elevator must have started to move down since it had been motionless.

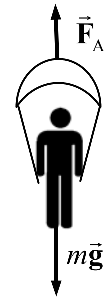
16. Choose UP to be the positive direction. Write Newton's 2nd law for the elevator.



$$\sum F = F_T - mg = ma \quad \rightarrow$$

$$a = \frac{F_T - mg}{m} = \frac{21{,}750\ \text{N} - (2125\ \text{kg})(9.80\ \text{m/s}^2)}{2125\ \text{kg}} = 0.4353\ \text{m/s}^2 \approx \boxed{0.44\ \text{m/s}^2}$$

17. (*a*) There will be two forces on the skydivers – their combined weight, and the upward force of air resistance, $\vec{\mathbf{F}}_A$. Choose up to be the positive direction. Write Newton's 2nd law for the skydivers.



$$\sum F = F_A - mg = ma \quad \rightarrow \quad 0.25mg - mg = ma \quad \rightarrow$$

$$a = -0.75g = -0.75\left(9.8\,\text{m/s}^2\right) = \boxed{-7.4\,\text{m/s}^2}$$

Due to the sign of the result, the direction of the acceleration is down.

(*b*) If they are descending at constant speed, then the net force on them must be zero, and so the force of air resistance must be equal to their weight.

$$F_A = mg = (132\text{ kg})\left(9.80\,\text{m/s}^2\right) = \boxed{1.29\times10^3\,\text{N}}$$

18. (*a*) Use Eq. 2-11c to find the speed of the person just before striking the ground. Take down to be the positive direction. For the person, $v_0 = 0$, $y - y_0 = 3.9$ m, and $a = 9.8\,\text{m/s}^2$.

$$v^2 - v_0^2 = 2a(y - y_0) \quad \rightarrow \quad v = \sqrt{2a(y-y_0)} = \sqrt{2\left(9.8\,\text{m/s}^2\right)(3.9\text{ m})} = 8.743 = \boxed{8.7\,\text{m/s}}$$

(*b*) For the deceleration, use Eq. 2-11c to find the average deceleration, choosing down to be positive.

$$v_0 = 8.743\,\text{m/s} \qquad v = 0 \qquad y - y_0 = 0.70\text{ m} \qquad v^2 - v_0^2 = 2a(y-y_0) \quad \rightarrow$$

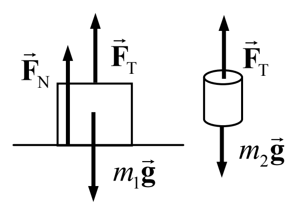
$$a = \frac{-v_0^2}{2\Delta y} = \frac{-(8.743\,\text{m/s})^2}{2(0.70\text{ m})} = -54.6\,\text{m/s}^2$$

The average force is found from Newton's 2nd law.

$$F = ma = (42\text{ kg})\left(-54.6\,\text{m/s}^2\right) = \boxed{-2.3\times10^3\,\text{N}}.$$

The negative sign shows that the force is in the negative direction, which is upward.

19. Free body diagrams for the box and the weight are shown below. The tension exerts the same magnitude of force on both objects.



(*a*) If the weight of the hanging weight is less than the weight of the box, the objects will not move, and the tension will be the same as the weight of the hanging weight. The acceleration of the box will also be zero, and so the sum of the forces on it will be zero. For the box,

$$F_N + F_T - m_1 g = 0 \quad \rightarrow \quad F_N = m_1 g - F_T = m_1 g - m_2 g = 77.0\text{N} - 30.0\text{ N} = \boxed{47.0\text{ N}}$$

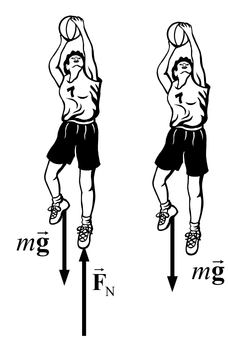
(*b*) The same analysis as for part (*a*) applies here.

$$F_N = m_1 g - m_2 g = 77.0\text{ N} - 60.0\text{ N} = \boxed{17.0\text{ N}}$$

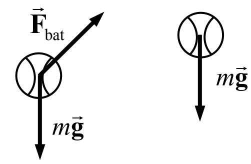
(*c*) Since the hanging weight has more weight than the box on the table, the box on the table will be lifted up off the table, and normal force of the table on the box will be $\boxed{0\text{ N}}$.

20. (*a*) Just before the player leaves the ground on a jump, the forces on the player would be his weight and the force of the floor pushing up the player. If the player is jumping straight up, then the force of the floor pushing on the player will be straight up – a normal force. See the first diagram. In this case, while they are touching the floor, $F_N > mg$.

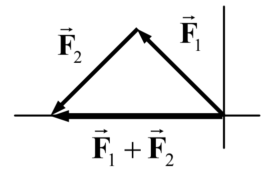
(*b*) While the player is in the air, the only force on the player is their weight. See the second diagram.



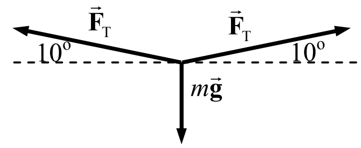
21. (*a*) Just as the ball is being hit, if we ignore air resistance, there are two main forces on the ball – the weight of the ball, and the force of the bat on the ball.
(*b*) As the ball flies toward the outfield, the only force on it is its weight, if air resistance is ignored.



22. The two forces must be oriented so that the northerly component of the first force is exactly equal to the southerly component of the second force. Thus the second force must act $\boxed{\text{southwesterly}}$. See the diagram.



23. Consider the point in the rope directly below Arlene. That point can be analyzed as having three forces on it – Arlene's weight, the tension in the rope towards the right point of connection, and the tension in the rope towards the left point of connection. Assuming the rope is massless, those two tensions will be of the same magnitude. Since the point is not accelerating the sum of the forces must be zero. In particular, consider the sum of the vertical forces on that point, with UP as the positive direction.



$$\sum F = F_{\text{T}} \sin 10.0^{\circ} + F_{\text{T}} \sin 10.0^{\circ} - mg = 0 \quad \rightarrow$$

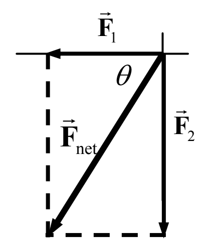
$$F_{\text{T}} = \frac{mg}{2\sin 10.0^{\circ}} = \frac{(50.0\text{ kg})(9.80\text{ m/s}^2)}{2\sin 10.0^{\circ}} = \boxed{1.41\times 10^3\text{ N}}$$

24. The net force in each case is found by vector addition with components.
(*a*) $F_{\text{Net x}} = -F_1 = -10.2\text{ N} \quad F_{\text{Net y}} = -F_2 = -16.0\text{ N}$

$$F_{\text{Net}} = \sqrt{(-10.2)^2 + (-16.0)^2} = \boxed{19.0\text{ N}} \qquad \theta = \tan^{-1}\frac{-16.0}{-10.2} = 57.5^{\circ}$$

The actual angle from the *x*-axis is then 237.5°.

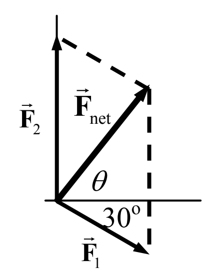
$$a = \frac{F_{\text{Net}}}{m} = \frac{19.0\text{ N}}{27.0\text{ kg}} = \boxed{0.703\text{ m/s}^2} \text{ at } \boxed{237^{\circ}}$$



(*b*) $F_{\text{Net x}} = F_1 \cos 30^{\circ} = 8.83\text{ N} \quad F_{\text{Net y}} = F_2 - F_1 \sin 30^{\circ} = 10.9\text{ N}$

$$F_{\text{Net}} = \sqrt{(8.83\text{ N})^2 + (10.9\text{ N})^2} = \boxed{14.0\text{ N}} \qquad \theta = \tan^{-1}\frac{10.9}{8.83} = \boxed{51.0^{\circ}}$$

$$a = \frac{F_{\text{Net}}}{m} = \frac{14.0\text{ N}}{27.0\text{ kg}} = \boxed{0.520\text{ m/s}^2} \text{ at } \boxed{51.0^{\circ}}$$



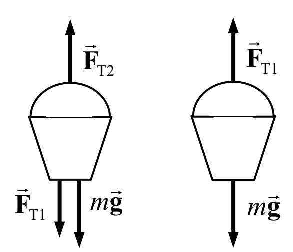
25. We draw free-body diagrams for each bucket.
(*a*) Since the buckets are at rest, their acceleration is 0. Write Newton's 2nd law for each bucket, calling UP the positive direction.

$$\sum F_1 = F_{\text{T1}} - mg = 0 \quad \rightarrow$$

$$F_{\text{T1}} = mg = (3.2\text{ kg})(9.8\text{ m/s}^2) = \boxed{31\text{ N}}$$

$$\sum F_2 = F_{\text{T2}} - F_{\text{T1}} - mg = 0 \quad \rightarrow$$

$$F_{\text{T2}} = F_{\text{T1}} + mg = 2mg = 2(3.2\text{ kg})(9.8\text{ m/s}^2) = \boxed{63\text{ N}}$$



Top (# 2) Bottom (# 1)

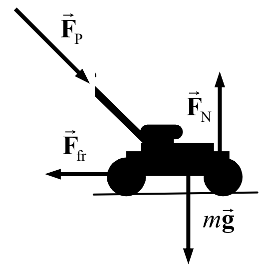
(*b*) Now repeat the analysis, but with a non-zero acceleration. The free-body diagrams are unchanged.

$$\sum F_1 = F_{T1} - mg = ma \quad \rightarrow$$

$$F_{T1} = mg + ma = (3.2\text{ kg})\left(9.80\text{ m/s}^2 + 1.60\text{ m/s}^2\right) = \boxed{36\text{ N}}$$

$$\sum F_2 = F_{T2} - F_{T1} - mg = ma \quad \rightarrow \quad F_{T2} = F_{T1} + mg + ma = 2F_{T1} = \boxed{73\text{ N}}$$

26. (*a*) We assume that the mower is being pushed to the right. $\vec{\mathbf{F}}_{fr}$ is the friction force, and $\vec{\mathbf{F}}_P$ is the pushing force along the handle.



(*b*) Write Newton's 2nd law for the horizontal direction. The forces must sum to 0 since the mower is not accelerating.

$$\sum F_x = F_P \cos 45.0^\circ - F_{fr} = 0 \quad \rightarrow$$

$$F_{fr} = F_P \cos 45.0^\circ = (88.0\text{ N})\cos 45.0^\circ = \boxed{62.2\text{ N}}$$

(*c*) Write Newton's 2nd law for the vertical direction. The forces must sum to 0 since the mower is not accelerating in the vertical direction.

$$\sum F_y = F_N - mg - F_P \sin 45.0^\circ = 0 \quad \rightarrow$$

$$F_N = mg + F_P \sin 45^\circ = (14.0\text{ kg})\left(9.80\text{ m/s}^2\right) + (88.0\text{ N})\sin 45.0^\circ = \boxed{199\text{ N}}$$

(*d*) First use Eq. 2-11a to find the acceleration.

$$v - v_0 = at \quad \rightarrow \quad a = \frac{v - v_0}{t} = \frac{1.5\text{ m/s} - 0}{2.5\text{ s}} = 0.60\text{ m/s}^2$$

Now use Newton's 2nd law for the *x* direction to find the necessary pushing force.

$$\sum F_x = F_P \cos 45.0^\circ - F_f = ma \quad \rightarrow$$

$$F_P = \frac{F_f + ma}{\cos 45.0^\circ} = \frac{62.2\text{ N} + (14.0\text{ kg})\left(0.60\text{ m/s}^2\right)}{\cos 45.0^\circ} = \boxed{99.9\text{ N}}$$

27. Choose the *y* direction to be the "forward" direction for the motion of the snowcats, and the *x* direction to be to the right on the diagram in the textbook. Since the housing unit moves in the forward direction on a straight line, there is no acceleration in the *x* direction, and so the net force in the *x* direction must be 0. Write Newton's 2nd law for the *x* direction.

$$\sum F_x = F_{Ax} + F_{Bx} = 0 \quad \rightarrow \quad -F_A \sin 50^\circ + F_B \sin 30^\circ = 0 \quad \rightarrow$$

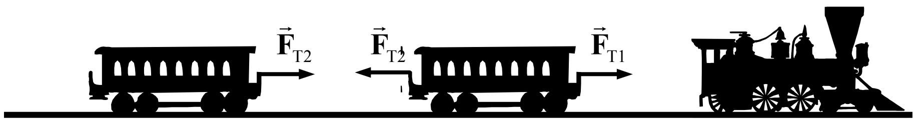
$$F_B = \frac{F_A \sin 50^\circ}{\sin 30^\circ} = \frac{(4500\text{ N})\sin 50^\circ}{\sin 30^\circ} = \boxed{6.9\times 10^3\text{ N}}$$

Since the *x* components add to 0, the magnitude of the vector sum of the two forces will just be the sum of their *y* components.

$$\sum F_y = F_{Ay} + F_{By} = F_A \cos 50^\circ + F_B \cos 30^\circ = (4500\text{ N})\cos 50^\circ + (6900\text{ N})\cos 30^\circ = \boxed{8.9\times 10^3\text{ N}}$$

28. Since all forces of interest in this problem are horizontal, draw the free-body diagram showing only the horizontal forces. $\vec{\mathbf{F}}_{T1}$ is the tension in the coupling between the locomotive and the first car, and it pulls to the right on the first car. $\vec{\mathbf{F}}_{T2}$ is the tension in the coupling between the first car an the second car. It pulls to the right on car 2, labeled $\vec{\mathbf{F}}_{T2R}$ and to the left on car 1, labeled $\vec{\mathbf{F}}_{T2L}$. Both cars

have the same mass m and the same acceleration a. Note that $\left|\vec{\mathbf{F}}_{\text{T2R}}\right| = \left|\vec{\mathbf{F}}_{\text{T2L}}\right| = F_{T2}$ by Newton's 3rd law.



Write a Newton's 2nd law expression for each car.

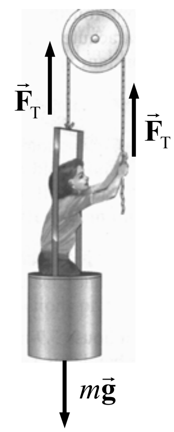
$$\sum F_1 = F_{T1} - F_{T2} = ma \qquad \sum F_2 = F_{T2} = ma$$

Substitute the expression for ma from the second expression into the first one.

$$F_{T1} - F_{T2} = ma = F_{T2} \quad \rightarrow \quad F_{\text{T1}} = 2F_{\text{T2}} \quad \rightarrow \quad \boxed{F_{\text{T1}}/F_{\text{T2}} = 2}$$

This can also be discussed in the sense that the tension between the locomotive and the first car is pulling 2 cars, while the tension between the cars is only pulling one car.

29. The window washer pulls down on the rope with her hands with a tension force F_{T}, so the rope pulls up on her hands with a tension force F_{T}. The tension in the rope is also applied at the other end of the rope, where it attaches to the bucket. Thus there is another force F_{T} pulling up on the bucket. The bucket-washer combination thus has a net force of $2F_{\text{T}}$ upwards. See the adjacent free-body diagram, showing only forces on the bucket-washer combination, not forces exerted by the combination (the pull down on the rope by the person) or internal forces (normal force of bucket on person).



(*a*) Write Newton's 2nd law in the vertical direction, with up as positive. The net force must be zero if the bucket and washer have a constant speed.

$$\sum F = F_{\text{T}} + F_{\text{T}} - mg = 0 \ \rightarrow \ 2F_{\text{T}} = mg \ \rightarrow$$

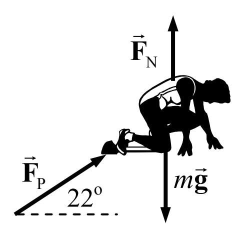
$$F_{\text{T}} = \frac{mg}{2} = \frac{(65\text{ kg})(9.8\,\text{m/s}^2)}{2} = \boxed{320\text{ N}}$$

(*b*) Now the force is increased by 15%, so $F_{\text{T}} = 320\text{ N}(1.15) = 368\text{ N}$. Again write Newton's 2nd law, but with a non-zero acceleration.

$$\sum F = F_{\text{T}} + F_{\text{T}} - mg = ma \quad \rightarrow$$

$$a = \frac{2F_{\text{T}} - mg}{m} = \frac{2(368\text{ N}) - (65\text{ kg})(9.80\,\text{m/s}^2)}{65\text{ kg}} = \boxed{1.5\,\text{m/s}^2}$$

30. Since the sprinter exerts a force of 720 N on the ground at an angle of 22° below the horizontal, by Newton's 3rd law the ground will exert a force of 720 N on the sprinter at an angle of 22° above the horizontal. A free-body diagram for the sprinter is shown.



(*a*) The horizontal acceleration will be found from the net horizontal force. Using Newton's 2nd law, we have the following.

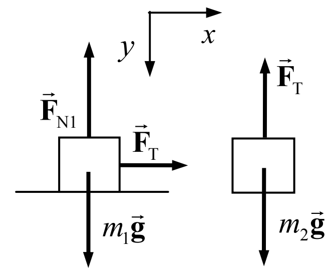
$$\sum F_x = F_{\text{P}}\cos 22^\circ = ma_x \quad \rightarrow \quad a_x = \frac{F_{\text{P}}\cos 22^\circ}{m} = \frac{(720\text{ N})\cos 22^\circ}{65\text{ kg}}$$

$$= 10.27\,\text{m/s}^2 \approx \boxed{1.0\times 10^1\ \text{m/s}^2}$$

(*b*) Eq. 2-11a is used to find the final speed. The starting speed is 0.

$$v = v_0 + at \quad \rightarrow \quad v = 0 + at = \left(10.27\,\text{m/s}^2\right)\left(0.32\ \text{s}\right) = 3.286\,\text{m/s} \approx \boxed{3.3\,\text{m/s}}$$

31. (*a*) See the free-body diagrams included.

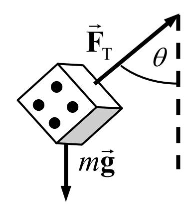


(*b*) For block 1, since there is no motion in the vertical direction, we have $F_{\text{N1}} = m_1 g$. We write Newton's 2nd law for the x direction: $\sum F_{1x} = F_{\text{T}} = m_1 a_{1x}$. For block 2, we only need to consider vertical forces: $\sum F_{2y} = m_2 g - F_{\text{T}} = m_2 a_{2y}$. Since the two blocks are connected, the magnitudes of their accelerations will be the same, and so let $a_{1x} = a_{2y} = a$. Combine the two force equations from above, and solve for a by substitution.

$$F_{\text{T}} = m_1 a \qquad m_2 g - F_{\text{T}} = m_2 a \quad \rightarrow \quad m_2 g - m_1 a = m_2 a \quad \rightarrow$$

$$m_1 a + m_2 a = m_2 g \quad \rightarrow \quad \boxed{a = g\frac{m_2}{m_1 + m_2} \qquad F_{\text{T}} = m_1 a = g\frac{m_1 m_2}{m_1 + m_2}}$$

32. Consider a free-body diagram of the dice. The car is moving to the right. The acceleration of the dice is found from Eq. 2-11a.



$$v = v_0 + = a_x t \quad \rightarrow \quad a_x = \frac{v - v_0}{t} = \frac{28\,\text{m/s} - 0}{6.0\ \text{s}} = 4.67\,\text{m/s}^2$$

Now write Newton's 2nd law for both the vertical (y) and horizontal (x) directions.

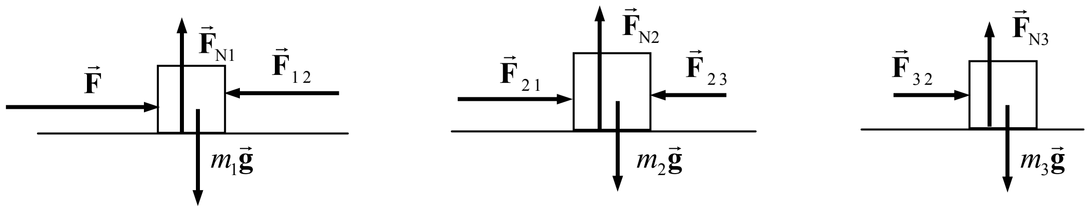
$$\sum F_y = F_{\text{T}}\cos\theta - mg = 0 \quad \rightarrow \quad F_{\text{T}} = \frac{mg}{\cos\theta} \qquad \sum F_x = F_{\text{T}}\sin\theta = ma_x$$

Substitute the expression for the tension from the y equation into the x equation.

$$ma_x = F_{\text{T}}\sin\theta = \frac{mg}{\cos\theta}\sin\theta = mg\tan\theta \quad \rightarrow \quad a_x = g\tan\theta$$

$$\theta = \tan^{-1}\frac{a_x}{g} = \tan^{-1}\frac{4.67\,\text{m/s}^2}{9.8\,\text{m/s}^2} = \boxed{25^{\circ}}$$

33. (*a*) In the free-body diagrams below, $\vec{\mathbf{F}}_{12}$ = force on block 1 exerted by block 2, $\vec{\mathbf{F}}_{21}$ = force on block 2 exerted by block 1, $\vec{\mathbf{F}}_{23}$ = force on block 2 exerted by block 3, and $\vec{\mathbf{F}}_{32}$ = force on block 3 exerted by block 2. The magnitudes of $\vec{\mathbf{F}}_{21}$ and $\vec{\mathbf{F}}_{12}$ are equal, and the magnitudes of $\vec{\mathbf{F}}_{23}$ and $\vec{\mathbf{F}}_{32}$ are equal, by Newton's 3rd law.



(*b*) All of the vertical forces on each block add up to zero, since there is no acceleration in the vertical direction. Thus for each block, $F_N = mg$. For the horizontal direction, we have

$$\sum F = F - F_{12} + F_{21} - F_{23} + F_{32} = F = (m_1 + m_2 + m_3)a \quad \rightarrow \quad \boxed{a = \frac{F}{m_1 + m_2 + m_3}}$$

(*c*) For each block, the net force must be *ma* by Newton's 2nd law. Each block has the same acceleration since they are in contact with each other.

$$\boxed{F_{1net} = \frac{m_1 F}{m_1 + m_2 + m_3}} \qquad \boxed{F_{2net} = \frac{m_2 F}{m_1 + m_2 + m_3}} \qquad \boxed{F_{3net} = \frac{m_3 F}{m_1 + m_2 + m_3}}$$

(*d*) From the free-body diagram, we see that for m_3, $F_{32} = F_{3net} = \boxed{\frac{m_3 F}{m_1 + m_2 + m_3}}$. And by Newton's 3rd law, $F_{32} = F_{23} = F_{3net} = \boxed{\frac{m_3 F}{m_1 + m_2 + m_3}}$. Of course, $\vec{\mathbf{F}}_{23}$ and $\vec{\mathbf{F}}_{32}$ are in opposite directions.

Also from the free-body diagram, we see that for m_1,

$$F - F_{12} = F_{1net} = \frac{m_1 F}{m_1 + m_2 + m_3} \quad \rightarrow F_{12} = F - \frac{m_1 F}{m_1 + m_2 + m_3} \quad \rightarrow \quad \boxed{F_{12} = \frac{(m_2 + m_3)F}{m_1 + m_2 + m_3}}.$$ By Newton's 3rd law, $F_{12} = F_{21} = \boxed{\frac{(m_2 + m_3)F}{m_1 + m_2 + m_3}}$.

(*e*) Using the given values, $a = \frac{F}{m_1 + m_2 + m_3} = \frac{96.0\ \text{N}}{36.0\ \text{kg}} = \boxed{2.67\ \text{m/s}^2}$. Since all three masses are the same value, the net force on each mass is $F_{net} = ma = (12.0\ \text{kg})(2.67\ \text{m/s}^2) = 32.0\ \text{N}$.

This is also the value of F_{32} and F_{23}. The value of F_{12} and F_{21} is

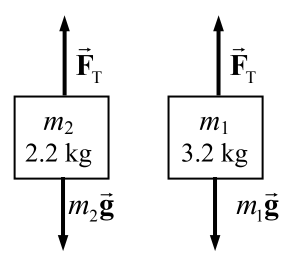
$$F_{12} = F_{21} = (m_2 + m_3)a = (24\ \text{kg})(2.67\ \text{m/s}^2) = 64.0\ \text{N}.$$

To summarize:

$$F_{\text{net 1}} = F_{\text{net 2}} = F_{\text{net 3}} = \boxed{32.0\ \text{N}} \qquad F_{12} = F_{21} = \boxed{64.0\ \text{N}} \qquad F_{23} = F_{32} = \boxed{32.0\ \text{N}}$$

The values make sense in that in order of magnitude, we should have $F > F_{21} > F_{32}$, since F is the net force pushing the entire set of blocks, F_{12} is the net force pushing the right two blocks, and F_{23} is the net force pushing the right block only.

34. First, draw a free-body diagram for each mass. Notice that the same tension force is applied to each mass. Choose UP to be the positive direction. Write Newton's 2nd law for each of the masses.



$$F_T - m_2 g = m_2 a_2 \qquad F_T - m_1 g = m_1 a_1$$

Since the masses are joined together by the cord, their accelerations will have the same magnitude but opposite directions. Thus $a_1 = -a_2$. Substitute this into the force expressions and solve for the acceleration by subtracting the second equation from the first.

$$F_T - m_1 g = -m_1 a_2 \quad \rightarrow \quad F_T = m_1 g - m_1 a_2$$

$$F_T - m_2 g = m_2 a_2 \quad \rightarrow \quad m_1 g - m_1 a_2 - m_2 g = m_2 a_2 \quad \rightarrow \quad m_1 g - m_2 g = m_1 a_2 + m_2 a_2$$

$$a_2 = \frac{m_1 - m_2}{m_1 + m_2} g = \frac{3.2\ \text{kg} - 2.2\ \text{kg}}{3.2\ \text{kg} + 2.2\ \text{kg}}(9.8\ \text{m/s}^2) = 1.815\ \text{m/s}^2$$

The lighter block starts with a speed of 0, and moves a distance of 1.80 meters with the acceleration found above. Using Eq. 2-11c, the velocity of the lighter block at the end of this accelerated motion can be found.

$$v^2 - v_0^2 = 2a(y - y_0) \quad \rightarrow \quad v = \sqrt{v_0^2 + 2a(y - y_0)} = \sqrt{0 + 2(1.815\,\mathrm{m/s^2})(1.80\ \mathrm{m})} = 2.556\,\mathrm{m/s}$$

Now the lighter block has different conditions of motion. Once the heavier block hits the ground, the tension force disappears, and the lighter block is in free fall. It has an initial speed of 2.556 m/s upward as found above, with an acceleration of –9.8 m/s^2 due to gravity. At its highest point, its speed will be 0. Eq. 2-11c can again be used to find the height to which it rises.

$$v^2 - v_0^2 = 2a(y - y_0) \quad \rightarrow \quad (y - y_0) = \frac{v^2 - v_0^2}{2a} = \frac{0 - (2.556\,\mathrm{m/s})^2}{2(-9.8\,\mathrm{m/s^2})} = 0.33\ \mathrm{m}$$

Thus the total height above the ground is 1.80 m + 1.80 m + 0.33 m = $\boxed{3.93\ \mathrm{m}}$.

35. Please refer to the free-body diagrams given in the textbook for this problem. Initially, treat the two boxes and the rope as a single system. Then the only accelerating force on the system is $\vec{\mathbf{F}}_{\mathrm{P}}$. The mass of the system is 23.0 kg, and so using Newton's 2nd law, the acceleration of the system is $a = \frac{F_{\mathrm{P}}}{m} = \frac{40.0\ \mathrm{N}}{23.0\ \mathrm{kg}} = \boxed{1.74\,\mathrm{m/s^2}}$. This is the acceleration of each piece of the system.

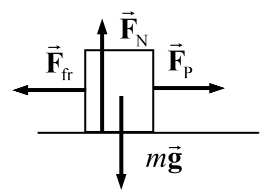
Now consider the left box alone. The only force on it is $\vec{\mathbf{F}}_{\mathrm{BT}}$, and it has the acceleration found above. Thus F_{BT} can be found from Newton's 2nd law.

$$F_{\mathrm{BT}} = m_{\mathrm{B}}a = (12.0\ \mathrm{kg})(1.74\,\mathrm{m/s^2}) = \boxed{20.9\ \mathrm{N}}.$$

Now consider the rope alone. The net force on it is $\vec{\mathbf{F}}_{\mathrm{TA}} - \vec{\mathbf{F}}_{\mathrm{TB}}$, and it also has the acceleration found above. Thus F_{TA} can be found from Newton's 2nd law.

$$F_{\mathrm{TA}} - F_{\mathrm{TB}} = m_C a \quad \rightarrow \quad F_{\mathrm{TA}} = F_{\mathrm{TB}} + m_{\mathrm{C}}a = 20.9\ \mathrm{N} + (1.0\ \mathrm{kg})(1.74\,\mathrm{m/s^2}) = \boxed{22.6\ \mathrm{N}}$$

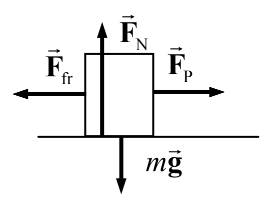
36. A free-body diagram for the crate is shown. The crate does not accelerate vertically, and so $F_{\mathrm{N}} = mg$. The crate does not accelerate horizontally, and so $F_{\mathrm{P}} = F_{\mathrm{fr}}$. Putting this together, we have



$$F_{\mathrm{P}} = F_{\mathrm{fr}} = \mu_k F_{\mathrm{N}} = \mu_k mg = (0.30)(35\ \mathrm{kg})(9.8\,\mathrm{m/s^2}) = 103 = \boxed{1.0\times10^2\,\mathrm{N}}$$

If the coefficient of kinetic friction is zero, then the horizontal force required is $\boxed{0\ \mathrm{N}}$, since there is no friction to counteract. Of course, it would take a force to START the crate moving, but once it was moving, no further horizontal force would be necessary to maintain the motion.

$\boxed{37.}$ A free-body diagram for the box is shown. Since the box does not accelerate vertically, $F_{\mathrm{N}} = mg$



(*a*) To start the box moving, the pulling force must just overcome the force of static friction, and that means the force of static friction will reach its maximum value of $F_{\mathrm{fr}} = \mu_s F_{\mathrm{N}}$. Thus we have for the starting motion,

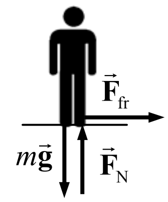
$$F_P = F_{fr} = \mu_s F_N = \mu_s mg \quad \rightarrow \quad \mu_s = \frac{F_P}{mg} = \frac{48.0 \text{ N}}{(5.0 \text{ kg})(9.8 \text{ m/s}^2)} = \boxed{0.98}$$

(*b*) The same force diagram applies, but now the friction is kinetic friction, and the pulling force is NOT equal to the frictional force, since the box is accelerating to the right.

$$\sum F = F_P - F_{fr} = ma \quad \rightarrow \quad F_P - \mu_k F_N = ma \quad \rightarrow \quad F_P - \mu_k mg = ma \quad \rightarrow$$

$$\mu_k = \frac{F_P - ma}{mg} = \frac{48.0 \text{ N} - (5.0 \text{ kg})(0.70 \text{ m/s}^2)}{(5.0 \text{ kg})(9.8 \text{ m/s}^2)} = \boxed{0.91}$$

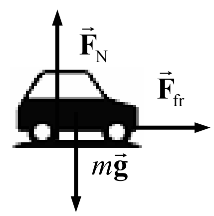
38. A free-body diagram for you as you stand on the train is shown. You do not accelerate vertically, and so $F_N = mg$. The maximum static frictional force is $\mu_s F_N$, and that must be greater than or equal to the force needed to accelerate you.



$$F_{fr} \geq ma \quad \rightarrow \quad \mu_s F_N \geq ma \quad \rightarrow \quad \mu_s mg \geq ma \quad \rightarrow \quad \mu_s \geq a/g = 0.20g/g = \boxed{0.20}$$

The static coefficient of friction must be at least 0.20 for you to not slide.

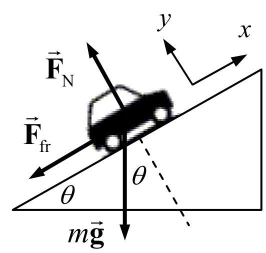
39. A free-body diagram for the accelerating car is shown. The car does not accelerate vertically, and so $F_N = mg$. The static frictional force is the accelerating force, and so $F_{fr} = ma$. If we assume the maximum acceleration, then we need the maximum force, and so the static frictional force would be its maximum value of $\mu_s F_N$. Thus we have



$$F_{fr} = ma \quad \rightarrow \quad \mu_s F_N = ma \quad \rightarrow \quad \mu_s mg = ma \quad \rightarrow$$

$$a = \mu_s g = 0.80(9.8 \text{ m/s}^2) = \boxed{7.8 \text{ m/s}^2}$$

40. See the included free-body diagram. To find the maximum angle, assume that the car is just ready to slide, so that the force of static friction is a maximum. Write Newton's 2nd law for both directions. Note that for both directions, the net force must be zero since the car is not accelerating.

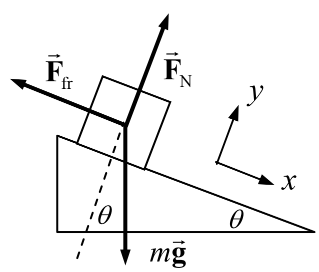


$$\sum F_y = F_N - mg\cos\theta = 0 \quad \rightarrow \quad F_N = mg\cos\theta$$

$$\sum F_x = mg\sin\theta - F_{fr} = 0 \quad \rightarrow \quad mg\sin\theta = F_{fr} = \mu_s F_N = \mu_s mg\cos\theta$$

$$\mu_s = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta = 0.8 \quad \rightarrow \quad \theta = \tan^{-1} 0.8 = 39^\circ = \boxed{40^\circ} \quad (1 \text{ sig fig})$$

41. Start with a free-body diagram. Write Newton's 2nd law for each direction.



$$\sum F_x = mg\sin\theta - F_{fr} = ma_x$$

$$\sum F_y = F_N - mg\cos\theta = ma_y = 0$$

Notice that the sum in the *y* direction is 0, since there is no motion (and hence no acceleration) in the *y* direction. Solve for the force of friction.

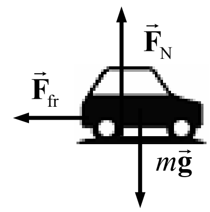
$$mg\sin\theta - F_{fr} = ma_x \quad \rightarrow$$

$$F_{fr} = mg\sin\theta - ma_x = (15.0 \text{ kg})\left[(9.80 \text{ m/s}^2)(\sin 32^\circ) - 0.30 \text{ m/s}^2\right] = 73.40 \text{ N} \approx \boxed{73 \text{ N}}$$

Now solve for the coefficient of kinetic friction. Note that the expression for the normal force comes from the y direction force equation above.

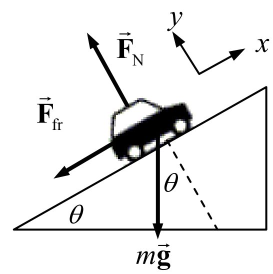
$$F_{\text{fr}} = \mu_k F_{\text{N}} = \mu_k mg\cos\theta \quad\rightarrow\quad \mu_k = \frac{F_{\text{fr}}}{mg\cos\theta} = \frac{73.40\ \text{N}}{(15.0\ \text{kg})(9.80\ \text{m/s}^2)(\cos 32^\circ)} = \boxed{0.59}$$

42. The direction of travel for the car is to the right, and that is also the positive horizontal direction. Using the free-body diagram, write Newton's 2nd law in the x direction for the car on the level road. We assume that the car is just on the verge of skidding, so that the magnitude of the friction force is $F_{\text{fr}} = \mu_s F_{\text{N}}$.



$$\sum F_x = -F_{\text{fr}} = ma \qquad F_{\text{fr}} = -ma = -\mu_s mg \quad\rightarrow\quad \mu_s = \frac{a}{g} = \frac{4.80\ \text{m/s}^2}{9.80\ \text{m/s}^2} = 0.4898$$

Now put the car on an inclined plane. Newton's 2nd law in the x-direction for the car on the plane is used to find the acceleration. We again assume the car is on the verge of slipping, so the static frictional force is at its maximum.

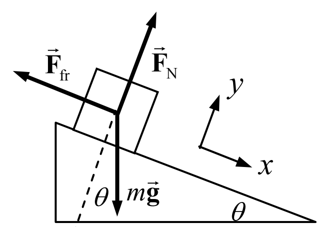


$$\sum F_x = -F_{\text{fr}} - mg\sin\theta = ma \quad\rightarrow$$

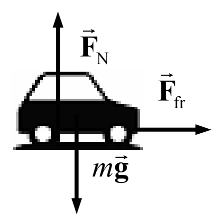
$$a = \frac{-F_{\text{fr}} - mg\sin\theta}{m} = \frac{-\mu_s mg\cos\theta - mg\sin\theta}{m} = -g\left(\mu_s\cos\theta + \sin\theta\right)$$

$$= -\left(9.80\ \text{m/s}^2\right)\left(0.4898\cos 13^\circ + \sin 13^\circ\right) = \boxed{-6.9\ \text{m/s}^2}$$

43. (*a*) Here is a free-body diagram for the box at rest on the plane. The force of friction is a STATIC frictional force, since the box is at rest.
(*b*) If the box were sliding down the plane, the only change is that the force of friction would be a KINETIC frictional force.
(*c*) If the box were sliding up the plane, the force of friction would be a KINETIC frictional force, and it would point down the plane, in the opposite direction to that shown in the diagram.



44. Assume that the static frictional force is the only force accelerating the racer. Then consider the free-body diagram for the racer as shown. It is apparent that the normal is equal to the weight, since there is no vertical acceleration. It is also assumed that the static frictional force is at its maximum. Thus



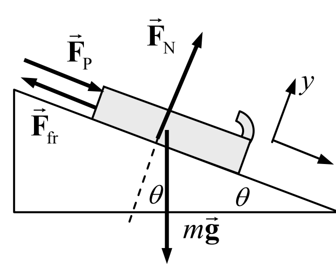
$$F_f = ma \quad\rightarrow\quad \mu_s mg = ma \quad\rightarrow\quad \mu_s = a/g$$

The acceleration of the racer can be calculated from Eq. 2-11b, with an initial speed of 0.

$$x - x_0 = v_0 t + \tfrac{1}{2}at^2 \quad\rightarrow\quad a = 2\left(x - x_0\right)/t^2$$

$$\mu_s = \frac{a}{g} = \frac{2\left(x - x_0\right)}{gt^2} = \frac{2(1000\ \text{m})}{\left(9.8\ \text{m/s}^2\right)(12\ \text{sec})^2} = \boxed{1.4}$$

45. A free-body diagram for the bobsled is shown. The acceleration of the sled is found from Eq. 2-11c. The final velocity also needs to be converted to m/s.



$$v = (60\ \text{km/h})\left(\frac{1\ \text{m/s}}{3.6\ \text{km/h}}\right) = 16.667\ \text{m/s}$$

$$v^2 - v_0^2 = 2a_x\left(x - x_0\right) \quad \rightarrow$$

$$a_x = \frac{v^2 - v_0^2}{2\left(x - x_0\right)} = \frac{\left(16.667\,\text{m/s}\right)^2 - 0}{2\left(75\text{ m}\right)} = 1.852\,\text{m/s}^2$$

Now write Newton's 2nd law for both directions. Since the sled does not accelerate in the *y* direction, the net force on the *y* direction must be 0. Then solve for the pushing force.

$$\sum F_y = F_\text{N} - mg\cos\theta = 0 \quad \rightarrow \quad F_\text{N} = mg\cos\theta$$

$$\sum F_x = mg\sin\theta + F_\text{P} - F_\text{fr} = ma_x$$

$$F_\text{P} = ma_x - mg\sin\theta + F_\text{fr} = ma_x - mg\sin\theta + \mu_k F_\text{N}$$

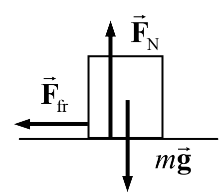
$$= ma_x - mg\sin\theta + \mu_k mg\cos\theta = m\left[a_x + g\left(\mu_k\cos\theta - \sin\theta\right)\right]$$

$$= \left(22\text{ kg}\right)\left[1.852\,\text{m/s}^2 + \left(9.8\,\text{m/s}^2\right)\left(0.10\cos 6.0^\circ - \sin 6.0^\circ\right)\right] = 39.6\text{ N} \approx \boxed{40\text{ N}}$$

46. The analysis of the blocks at rest can be done exactly the same as that presented in Example 4-20, up to the equation for the acceleration, $a = \dfrac{m_{II}g - F_\text{fr}}{m_I + m_{II}}$. Now, for the stationary case, the force of friction is static friction. To find the minimum value of m_I, we assume the maximum static frictional force. Thus $a = \dfrac{m_{II}g - \mu_s m_I g}{m_I + m_{II}}$. Finally, for the system to stay at rest, the acceleration must be zero. Thus

$$m_{II}g - \mu_s m_I g = 0 \quad \rightarrow \quad m_I = m_{II}/\mu_s = 2.0\text{ kg}/0.30 = \boxed{6.7\text{ kg}}$$

47. A free-body diagram for the box is shown, assuming that it is moving to the right. The "push" is not shown on the free-body diagram because as soon as the box moves away from the source of the pushing force, the push is no longer applied to the box. It is apparent from the diagram that $F_\text{N} = mg$ for the vertical direction. We write Newton's 2nd law for the horizontal direction, with positive to the right, to find the acceleration of the box.



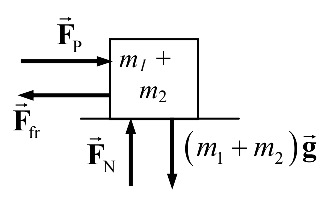
$$\sum F_x = -F_\text{fr} = ma \quad \rightarrow \quad ma = -\mu_k F_\text{N} = -\mu_k mg \quad \rightarrow$$

$$a = -\mu_k g = -0.2\left(9.8\,\text{m/s}^2\right) = -1.96\,\text{m/s}^2$$

Eq. 2-11c can be used to find the distance that the box moves before stopping. The initial speed is 4.0 m/s, and the final speed will be 0.

$$v^2 - v_0^2 = 2a\left(x - x_0\right) \quad \rightarrow \quad x - x_0 = \frac{v^2 - v_0^2}{2a} = \frac{0 - \left(4.0\,\text{m/s}\right)^2}{2\left(-1.96\,\text{m/s}^2\right)} = \boxed{4.1\text{ m}}$$

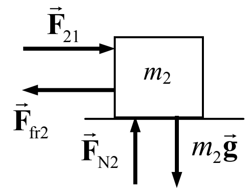
48. (*a*) Since the two blocks are in contact, they can be treated as a single object as long as no information is needed about internal forces (like the force of one block pushing on the other block). Since there is no motion in the vertical direction, it is apparent that $F_\text{N} = \left(m_1 + m_2\right)g$, and so $F_\text{fr} = \mu_k F_\text{N} = \mu_k\left(m_1 + m_2\right)g$. Write Newton's 2nd law for the horizontal direction.



$$\sum F_x = F_\text{P} - F_\text{fr} = \left(m_1 + m_2\right)a \quad \rightarrow$$

$$a = \frac{F_P - F_{fr}}{m_1 + m_2} = \frac{F_P - \mu_k (m_1 + m_2) g}{m_1 + m_2} = \frac{620\text{ N} - (0.15)(185\text{ kg})(9.8\text{ m/s}^2)}{185\text{ kg}} = \boxed{1.9\text{ m/s}^2}$$

(*b*) To solve for the contact forces between the blocks, an individual block must be analyzed. Look at the free-body diagram for the second block. $\vec{\mathbf{F}}_{21}$ is the force of the first block pushing on the second block. Again, it is apparent that $F_{N2} = m_2 g$ and so $F_{fr2} = \mu_k F_{N2} = \mu_k m_2 g$. Write Newton's 2nd law for the horizontal direction.

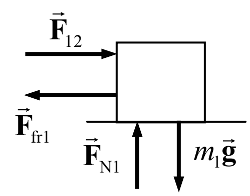


$$\sum F_x = F_{21} - F_{fr2} = m_2 a \quad \rightarrow$$

$$F_{21} = \mu_k m_2 g + m_2 a = (0.15)(110\text{ kg})(9.8\text{ m/s}^2) + (110\text{ kg})(1.9\text{ m/s}^2) = \boxed{3.7\times 10^2\text{ N}}$$

By Netwon's 3rd law, there will also be a 370 N force to the left on block # 1 due to block # 2.

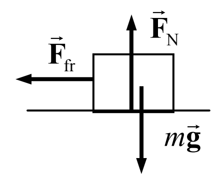
(*c*) If the crates are reversed, the acceleration of the system will remain the same – the analysis from part (a) still applies. We can also repeat the analysis from part (b) to find the force of one block on the other, if we simply change m_1 to m_2 in the free-body diagram and the resulting equations. The result would be



$$\sum F_x = F_{12} - F_{fr1} = m_1 a \quad \rightarrow$$

$$F_{12} = \mu_k m_1 g + m_1 a = (0.15)(75\text{ kg})(9.8\text{ m/s}^2) + (75\text{ kg})(1.9\text{ m/s}^2) = \boxed{2.5\times 10^2\text{ N}}$$

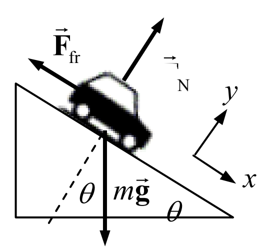
49. The force of static friction is what decelerates the crate if it is not sliding on the truck bed. If the crate is not to slide, but the maximum deceleration is desired, then the maximum static frictional force must be exerted, and so $F_{fr} = \mu_s F_N$. The direction of travel is to the right. It is apparent that $F_N = mg$ since there is no acceleration in the *y* direction. Write Newton's 2nd law for the truck in the horizontal direction.



$$\sum F_x = -F_{fr} = ma \quad \rightarrow \quad -\mu_s mg = ma \quad \rightarrow \quad a = -\mu_s g = -(0.75)(9.8\text{ m/s}^2) = \boxed{-7.4\text{ m/s}^2}$$

The negative sign indicates the direction of the acceleration – opposite to the direction of motion.

50. Consider a free-body diagram of the car on the icy inclined driveway. Assume that the car is not moving, but just ready to slip, so that the static frictional force has its maximum value of $F_{fr} = \mu_s F_N$. Write Newton's 2nd law in each direction for the car, with a net force of 0 in each case.



$$\sum F_y = F_N - mg\cos\theta = 0 \quad \rightarrow \quad F_N = mg\cos\theta$$

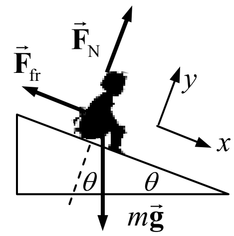
$$\sum F_x = mg\sin\theta - F_{fr} = 0 \quad \rightarrow \quad mg\sin\theta = \mu_s mg\cos\theta$$

$$\mu_s = \sin\theta/\cos\theta = \tan\theta \quad \rightarrow \quad \theta = \tan^{-1}\mu_s = \tan^{-1} 0.15 = 8.5^{\circ}$$

The car will not be able to stay at rest on any slope steeper than 8.5°.

$\boxed{\text{Only the driveway across the street is safe for parking.}}$

51. We assume that the child starts from rest at the top of the slide, and then slides a distance $x - x_0$ along the slide. A force diagram is shown for the child on the slide. First, ignore the frictional force and so consider the no-friction case. All of the motion is in the x direction, so we will only consider Newton's 2nd law for the x direction.



$$\sum F_x = mg\sin\theta = ma \quad \rightarrow \quad a = g\sin\theta$$

Use Eq. 2-11c to calculate the speed at the bottom of the slide.

$$v^2 - v_0^2 = 2a\left(x - x_0\right) \quad \rightarrow \quad v_{(\text{No friction})} = \sqrt{v_0^2 + 2a\left(x - x_0\right)} = \sqrt{2g\sin\theta\left(x - x_0\right)}$$

Now include kinetic friction. We must consider Newton's 2nd law in both the x and y directions now. The net force in the y direction must be 0 since there is no acceleration in the y direction.

$$\sum F_y = F_N - mg\cos\theta = 0 \quad \rightarrow \quad F_N = mg\cos\theta$$

$$\sum F_x = ma = mg\sin\theta - F_{fr} = mg\sin\theta - \mu_k F_N = mg\sin\theta - \mu_k mg\cos\theta$$

$$a = \frac{mg\sin\theta - \mu_k mg\cos\theta}{m} = g\left(\sin\theta - \mu_k\cos\theta\right)$$

With this acceleration, we can again use Eq. 2-11c to find the speed after sliding a certain distance.

$$v^2 - v_0^2 = 2a\left(x - x_0\right) \quad \rightarrow \quad v_{(\text{friction})} = \sqrt{v_0^2 + 2a\left(x - x_0\right)} = \sqrt{2g\left(\sin\theta - \mu_k\cos\theta\right)\left(x - x_0\right)}$$

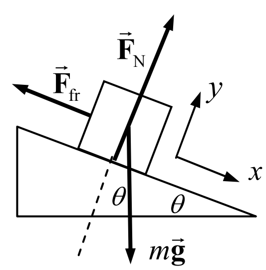
Now let the speed with friction be half the speed without friction, and solve for the coefficient of friction. Square the resulting equation and divide by $g\cos\theta$ to get the result.

$$v_{(\text{friction})} = \tfrac{1}{2} v_{(\text{No friction})} \quad \rightarrow \quad \sqrt{2g\left(\sin\theta - \mu_k\cos\theta\right)\left(x - x_0\right)} = \tfrac{1}{2}\sqrt{2g\left(\sin\theta\right)\left(x - x_0\right)}$$

$$2g\left(\sin\theta - \mu_k\cos\theta\right)\left(x - x_0\right) = \tfrac{1}{4}2g\left(\sin\theta\right)\left(x - x_0\right)$$

$$\mu_k = \tfrac{3}{4}\tan\theta = \tfrac{3}{4}\tan 28^\circ = \boxed{0.40}$$

52. (*a*) Consider the free-body diagram for the carton on the surface. There is no motion in the y direction and thus no acceleration in the y direction. Write Newton's 2nd law for both directions.



$$\sum F_x = F_N - mg\cos\theta = 0 \quad \rightarrow \quad F_N = mg\cos\theta$$

$$\sum F_x = mg\sin\theta - F_{fr} = ma$$

$$ma = mg\sin\theta - \mu_k F_N = mg\sin\theta - \mu_k mg\cos\theta$$

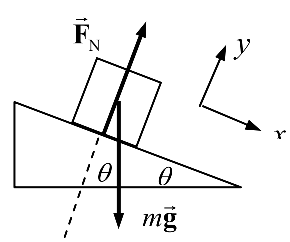
$$a = g\left(\sin\theta - \mu_k\cos\theta\right)$$

$$= \left(9.80\,\text{m/s}^2\right)\left(\sin 22.0^\circ - 0.12\cos 22.0^\circ\right) = 2.58 = \boxed{2.6\,\text{m/s}^2}$$

(*b*) Now use Eq. 2-11c, with an initial velocity of 0, to find the final velocity.

$$v^2 - v_0^2 = 2a\left(x - x_0\right) \quad \rightarrow \quad v = \sqrt{2a\left(x - x_0\right)} = \sqrt{2\left(2.58\,\text{m/s}^2\right)\left(9.30\text{ m}\right)} = \boxed{6.9\,\text{m/s}}$$

53. (*a*) Consider the free-body diagram for the carton on the frictionless surface. There is no acceleration in the y direction. Write Newton's 2nd law for the x direction.



$$\sum F_x = mg\sin\theta = ma \quad \rightarrow \quad a = g\sin\theta$$

Use Eq. 2-11c with $v_0 = -3.0\,\text{m/s}$ and $v = 0\,\text{m/s}$ to find the distance that it slides before stopping.

$$v^2 - v_0^2 = 2a(x - x_0) \quad \rightarrow$$

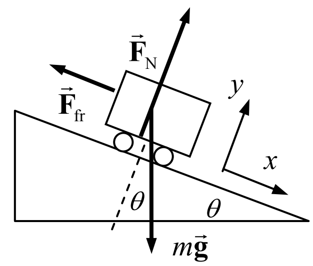
$$(x - x_0) = \frac{v^2 - v_0^2}{2a} = \frac{0 - (-3.0\,\text{m/s})^2}{2(9.8\,\text{m/s}^2)\sin 22.0^\circ} = \boxed{-1.2\ \text{m}}$$

The negative sign means that the block is displaced up the plane, which is the negative direction.

(*b*) The time for a round trip can be found from Eq. 2-11a. The free-body diagram (and thus the acceleration) is the same whether the block is rising or falling. For the entire trip, $v_0 = -3.0\,\text{m/s}$ and $v = +3.0\,\text{m/s}$.

$$v = v_0 + at \quad \rightarrow \quad t = \frac{v - v_0}{a} = \frac{(3.0\,\text{m/s}) - (-3.0\,\text{m/s})}{(9.8\,\text{m/s}^2)\sin 22^\circ} = \boxed{1.6\ \text{s}}$$

54. See the free-body diagram for the descending roller coaster. It starts its descent with $v_0 = (6.0\,\text{km/h})\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 1.667\,\text{m/s}$. The total displacement in the *x* direction is $x - x_0 = 45.0\ \text{m}$. Write Newton's second law for both the *x* and *y* directions.



$$\sum F_y = F_{\text{N}} - mg\cos\theta = 0 \quad \rightarrow \quad F_{\text{N}} = mg\cos\theta$$

$$\sum F_x = ma = mg\sin\theta - F_{\text{fr}} = mg\sin\theta - \mu_k F_{\text{N}} = mg\sin\theta - \mu_k mg\cos\theta$$

$$a = \frac{mg\sin\theta - \mu_k mg\cos\theta}{m} = g(\sin\theta - \mu_k\cos\theta)$$

Now use Eq. 2-11c to solve for the final velocity.

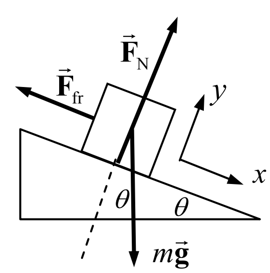
$$v^2 - v_0^2 = 2a(x - x_0) \quad \rightarrow$$

$$v = \sqrt{v_0^2 + 2a(x - x_0)} = \sqrt{v_0^2 + 2g(\sin\theta - \mu_k\cos\theta)(x - x_0)}$$

$$= \sqrt{(1.667\,\text{m/s})^2 + 2(9.8\,\text{m/s}^2)\left[\sin 45^\circ - (0.18)\cos 45^\circ\right](45.0\ \text{m})}$$

$$= 22.68\,\text{m/s} \approx \boxed{23\,\text{m/s}} \approx 82\,\text{km/h}$$

55. Consider a free-body diagram of the box. Write Newton's 2nd law for both directions. The net force in the *y* direction is 0 because there is no acceleration in the *y* direction.



$$\sum F_y = F_{\text{N}} - mg\cos\theta = 0 \quad \rightarrow \quad F_{\text{N}} = mg\cos\theta$$

$$\sum F_x = mg\sin\theta - F_{\text{fr}} = ma$$

Now solve for the force of friction and the coefficient of friction.

$$\sum F_y = F_{\text{N}} - mg\cos\theta = 0 \quad \rightarrow \quad F_{\text{N}} = mg\cos\theta$$

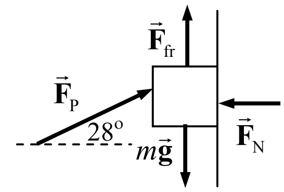
$$\sum F_x = mg\sin\theta - F_{\text{fr}} = ma$$

$$F_{\text{fr}} = mg\sin\theta - ma = m(g\sin\theta - a) = (18.0\ \text{kg})\left[(9.80\,\text{m/s}^2)(\sin 37.0^\circ) - 0.270\,\text{m/s}^2\right]$$

$$= 101.3\,\text{N} \approx \boxed{101\,\text{N}}$$

$$F_{\text{fr}} = \mu_k F_{\text{N}} = \mu_k mg\cos\theta \quad\rightarrow\quad \mu_k = \frac{F_{\text{fr}}}{mg\cos\theta} = \frac{101.3\text{ N}}{(18.0\text{ kg})(9.80\,\text{m/s}^2)\cos 37.0^\circ} = \boxed{0.719}$$

56. Consider a free-body diagram for the box, showing force on the box. When $F_{\text{P}} = 13\text{ N}$, the block does not move. Thus in that case, the force of friction is static friction, and must be at its maximum value, given by $F_{\text{fr}} = \mu_s F_{\text{N}}$. Write Newton's 2nd law in both the *x* and *y* directions. The net force in each case must be 0, since the block is at rest.



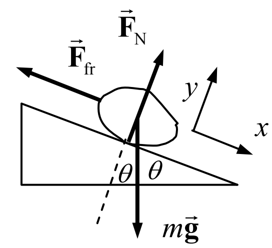
$$\sum F_x = F_{\text{P}}\cos\theta - F_{\text{N}} = 0 \quad\rightarrow\quad F_{\text{N}} = F_{\text{P}}\cos\theta$$

$$\sum F_y = F_{\text{fr}} + F_{\text{P}}\sin\theta - mg = 0 \quad\rightarrow\quad F_{\text{fr}} + F_{\text{P}}\sin\theta = mg$$

$$\mu_s F_{\text{N}} + F_{\text{P}}\sin\theta = mg \quad\rightarrow\quad \mu_s F_{\text{P}}\cos\theta + F_{\text{P}}\sin\theta = mg$$

$$m = \frac{F_{\text{P}}}{g}\left(\mu_s\cos\theta + \sin\theta\right) = \frac{13\text{ N}}{9.80\,\text{m/s}^2}\left(0.40\cos 28^\circ + \sin 28^\circ\right) = \boxed{1.1\text{ kg}}$$

57. (*a*) Consider the free-body diagram for the snow on the roof. If the snow is just ready to slip, then the static frictional force is at its maximum value, $F_{\text{fr}} = \mu_s F_{\text{N}}$. Write Newton's 2nd law in both directions, with the net force equal to zero since the snow is not accelerating.



$$\sum F_y = F_{\text{N}} - mg\cos\theta = 0 \quad\rightarrow\quad F_{\text{N}} = mg\cos\theta$$

$$\sum F_x = mg\sin\theta - F_{\text{fr}} = 0 \quad\rightarrow$$

$$mg\sin\theta = F_{\text{fr}} = \mu_s F_{\text{N}} = \mu_s mg\cos\theta \quad\rightarrow\quad \mu_s = \tan\theta = \tan 30^\circ = \boxed{0.58}$$

If $\mu_s > 0.58$, then the snow would not be on the verge of slipping.

(*b*) The same free-body diagram applies for the sliding snow. But now the force of friction is kinetic, so $F_{\text{fr}} = \mu_k F_{\text{N}}$, and the net force in the *x* direction is not zero. Write Newton's 2nd law for the *x* direction again, and solve for the acceleration.

$$\sum F_x = mg\sin\theta - F_{\text{fr}} = ma$$

$$a = \frac{mg\sin\theta - F_{\text{fr}}}{m} = \frac{mg\sin\theta - \mu_k mg\cos\theta}{m} = g\left(\sin\theta - \mu_k\cos\theta\right)$$

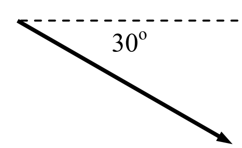
Use Eq. 2-11c with $v_i = 0$ to find the speed at the end of the roof.

$$v^2 - v_0^2 = 2a\left(x - x_0\right)$$

$$v = \sqrt{v_0 + 2a\left(x - x_0\right)} = \sqrt{2g\left(\sin\theta - \mu_k\cos\theta\right)\left(x - x_0\right)}$$

$$= \sqrt{2\left(9.8\,\text{m/s}^2\right)\left(\sin 30^\circ - (0.20)\cos 30^\circ\right)(5.0\text{ m})} = 5.66 = \boxed{5.7\,\text{m/s}}$$

(*c*) Now the problem becomes a projectile motion problem. The projectile has an initial speed of 5.7 m/s, directed at an angle of 30° below the horizontal. The horizontal component of the speed, (5.66 m/s) cos 30° = 4.90 m/s, will stay constant. The vertical component will change due to gravity. Define the positive direction to be downward. Then the starting vertical velocity is (5.66 m/s) sin 30° = 2.83 m/s, the vertical acceleration is 9.8 m/s^2, and the vertical displacement is 10.0 m. Use Eq. 2-11c to find the final vertical speed.



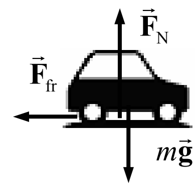
$$v_y^2 - v_{0y}^2 = 2a\left(y - y_0\right)$$

$$v_y = \sqrt{v_{y0}^2 + 2a\left(y - y_0\right)} = \sqrt{\left(2.83\,\text{m/s}\right)^2 + 2\left(9.8\,\text{m/s}^2\right)\left(10.0\text{ m}\right)} = 14.3\text{ m/s}$$

To find the speed when it hits the ground, the horizontal and vertical components of velocity must again be combined, according to the Pythagorean theorem.

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{\left(4.90\,\text{m/s}\right)^2 + \left(14.3\text{ m/s}\right)^2} = \boxed{15\,\text{m/s}}$$

58. (*a*) A free-body diagram for the car is shown, assuming that it is moving to the right. It is apparent from the diagram that $F_N = mg$ for the vertical direction. Write Newton's 2nd law for the horizontal direction, with positive to the right, to find the acceleration of the car. Since the car is assumed to NOT be sliding, use the maximum force of static friction.



$$\sum F_x = -F_{fr} = ma \;\rightarrow\; ma = -\mu_s F_N = -\mu_s mg \;\rightarrow\; a = -\mu_s g$$

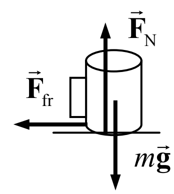
Eq. 2-11c can be used to find the distance that the car moves before stopping. The initial speed is given as v, and the final speed will be 0.

$$v^2 - v_0^2 = 2a\left(x - x_0\right) \;\rightarrow\; \left(x - x_0\right) = \frac{v^2 - v_0^2}{2a} = \frac{0 - v^2}{2\left(-\mu_s g\right)} = \boxed{\frac{v^2}{2\mu_s g}}$$

(*b*) Using the given values:

$$v = \left(95\,\text{km/h}\right)\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 26.38\,\text{m/s} \qquad \left(x - x_0\right) = \frac{v^2}{2\mu_s g} = \frac{\left(26.38\,\text{m/s}\right)^2}{2\left(0.75\right)\left(9.8\,\text{m/s}^2\right)} = \boxed{47\text{ m}}$$

59. A free-body diagram for the coffee cup is shown. Assume that the car is moving to the right, and so the acceleration of the car (and cup) will be to the left. The deceleration of the cup is caused by friction between the cup and the dashboard. For the cup to not slide on the dash, and to have the minimum deceleration time means the largest possible static frictional force is acting, so $F_{fr} = \mu_s F_N$. The normal force on the cup is equal to its weight, since there is no vertical acceleration. The horizontal acceleration of the cup is found from Eq. 2-11a, with a final velocity of zero.



$$v_0 = \left(45\,\text{km/h}\right)\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 12.5\,\text{m/s}$$

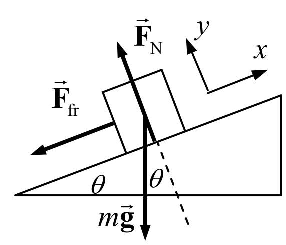
$$v - v_0 = at \;\rightarrow\; a = \frac{v - v_0}{t} = \frac{0 - 12.5\,\text{m/s}}{3.5\text{ s}} = -3.57\,\text{m/s}^2$$

Write Newton's 2nd law for the horizontal forces, considering to the right to be positive.

$$\sum F_x = -F_{fr} = ma \;\rightarrow\; ma = -\mu_s F_N = -\mu_s mg \;\rightarrow\; \mu_s = -\frac{a}{g} = -\frac{\left(-3.57\,\text{m/s}^2\right)}{9.80\,\text{m/s}^2} = \boxed{0.36}$$

60. We derive two expressions for acceleration – one from the kinematics, and one from the dynamics. From Eq. 2-11c with a starting speed of v_o up the plane and a final speed of zero, we have

$$v^2 - v_o^2 = 2a\left(x - x_0\right) \;\rightarrow\; a = \frac{-v_o^2}{2\left(x - x_0\right)} = \frac{-v_o^2}{2d}$$



Write Newton's 2nd law for both the x and y directions. Note that the net force in the y direction is zero, since the block does not accelerate in the y direction.

$$\sum F_y = F_N - mg\cos\theta = 0 \quad \rightarrow \quad F_N = mg\cos\theta$$

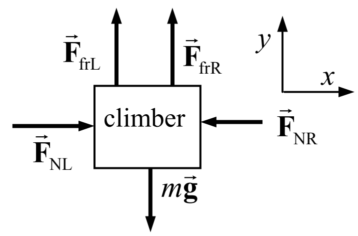
$$\sum F_x = -mg\sin\theta - F_{fr} = ma \quad \rightarrow \quad a = \frac{-mg\sin\theta - F_{fr}}{m}$$

Now equate the two expressions for the acceleration, substitute in the relationship between the frictional force and the normal force, and solve for the coefficient of friction.

$$a = \frac{-mg\sin\theta - F_{fr}}{m} = \frac{-v_o^2}{2d} \quad \rightarrow \quad \frac{mg\sin\theta + \mu_k mg\cos\theta}{m} = \frac{v_o^2}{2d} \quad \rightarrow$$

$$\boxed{\mu_k = \frac{v_o^2}{2gd\cos\theta} - \tan\theta}$$

61. Since the walls are vertical, the normal forces are horizontal, away from the wall faces. We assume that the frictional forces are at their maximum values, so $F_{fr} = \mu_s F_N$ applies at each wall. We assume that the rope in the diagram is not under any tension and so does not exert any forces. Consider the free-body diagram for the climber. F_{NR} is the normal force on the climber from the right wall, and F_{NL} is the normal force on the climber from the left wall. The static frictional forces are $F_{frL} = \mu_{sL} F_{NL}$ and $F_{frR} = \mu_{sR} F_{NR}$. Write Newton's 2nd law for both the x and y directions. The net force in each direction must be zero if the climber is stationary.



$$\sum F_x = F_{NL} - F_{NR} = 0 \quad \rightarrow \quad F_{NL} = F_{NR} \qquad \sum F_y = F_{frL} + F_{frR} - mg = 0$$

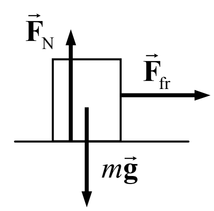
Substitute the information from the x equation into the y equation.

$$F_{frL} + F_{frR} = mg \quad \rightarrow \quad \mu_{sL} F_{NL} + \mu_{sR} F_{NR} = mg \quad \rightarrow \quad (\mu_{sL} + \mu_{sR}) F_{NL} = mg$$

$$F_{NL} = \frac{mg}{(\mu_{sL} + \mu_{sR})} = \frac{(75\text{ kg})(9.80\text{ m/s}^2)}{1.4} = 525\text{ N}$$

And so $F_{NL} = F_{NR} = 525\text{ N}$. These normal forces arise as Newton's 3rd law reaction forces to the climber pushing on the walls. Thus the climber must exert a force of at least $5.3\times10^2\text{ N}$ against each wall.

62. Notice the symmetry of this problem – in the first half of the motion, the object accelerates with a constant acceleration to a certain speed, and then in the second half of the motion, the object decelerates with the same magnitude of acceleration back to a speed of 0. Half the time elapses during the first segment of the motion, and half the distance is traveled during the first segment of the motion. Thus we analyze half of the motion, and then double the time found to get the total time.



Friction is the accelerating and decelerating force. We assume that the boxes do not slip on the belt since slippage would increase the travel time. To have the largest possible acceleration, and hence the largest possible force, so that the travel time can be a minimum, the box must be moved by the maximum value of the static frictional force, and so $F_{fr} = \mu_s F_N$. See the free-body diagram for the box on the first half of the trip, assuming that the conveyor belt is level. Since there is no vertical acceleration of the box, it is apparent that $F_N = mg$, and so $F_{fr} = \mu_s mg$. Use Newton's 2nd law in the horizontal direction to find the acceleration.

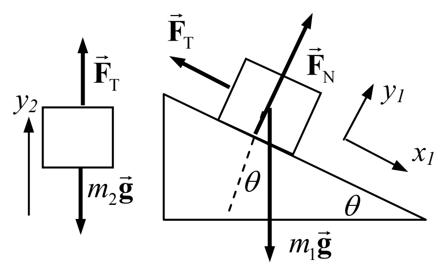
$$\sum F = F_{fr} = \mu_s mg = ma \quad \rightarrow \quad a = \mu_s g = (0.60)(9.8\,\text{m/s}^2) = 5.88\,\text{m/s}^2$$

Now use Eq. 2-11b to determine the time taken to move half the distance with the calculated acceleration, starting from rest.

$$d/2 = x - x_0 = v_0 t + \tfrac{1}{2}at^2 \quad \rightarrow \quad t = \sqrt{d/a}\,.$$

Thus the total time for the trip will be $t_{total} = 2\sqrt{d/a} = 2\sqrt{(11.0\text{ m})/(5.88\,\text{m/s}^2)} = \boxed{2.7\text{ s}}$

63. (*a*) Draw a free-body diagram for each block. Write Newton's 2nd law for each block. Notice that the acceleration of block # 1 in the y_1 direction will be zero, since it has no motion in the y_1 direction.



$$\sum F_{y1} = F_N - m_1 g\cos\theta = 0 \quad \rightarrow \quad F_N = m_1 g\cos\theta$$

$$\sum F_{x1} = m_1 g\sin\theta - F_T = m_1 a_{x1}$$

$$\sum F_{y2} = F_T - m_2 g = m_2 a_{y2} \quad \rightarrow \quad F_T = m_2(g + a_{y2})$$

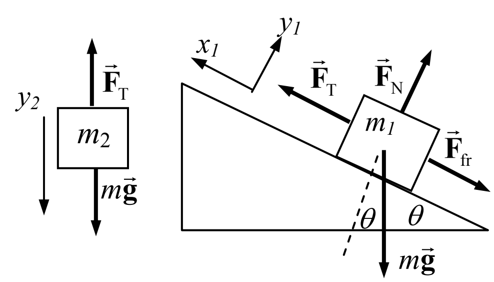
Since the blocks are connected by the cord, $a_{y2} = a_{x1} = a$. Substitute the expression for the tension force from the last equation into the x direction equation for block 1, and solve for the acceleration.

$$m_1 g\sin\theta - m_2(g + a) = m_1 a \quad \rightarrow \quad m_1 g\sin\theta - m_2 g = m_1 a + m_2 a$$

$$a = \boxed{g\frac{(m_1\sin\theta - m_2)}{(m_1 + m_2)}}$$

(*b*) If the acceleration is to be down the plane, it must be positive. That will happen if $\boxed{m_1\sin\theta > m_2 \ \ (\text{down the plane})}$. The acceleration will be up the plane (negative) if $\boxed{m_1\sin\theta < m_2 \ \ (\text{up the plane})}$. If $m_1\sin\theta = m_2$, then the system will not accelerate. It will move with a constant speed if set in motion by a push.

$\boxed{64.}$ (*a*) Given that m_2 is moving down, m_1 must be moving up the incline, and so the force of kinetic friction on m_1 will be directed down the incline. Since the blocks are tied together, they will both have the same acceleration, and so $a_{y2} = a_{x1} = a$. Write Newton's 2nd law for each mass.



$$\sum F_{y2} = mg - F_T = ma \quad \rightarrow \quad F_T = mg - ma$$

$$\sum F_{x1} = F_T - mg\sin\theta - F_{fr} = ma$$

$$\sum F_{y1} = F_N - mg\cos\theta = 0 \quad \rightarrow \quad F_N = mg\cos\theta$$

Take the information from the two y equations and substitute into the x equation to solve for the acceleration.

$$mg - ma - mg\sin\theta - \mu_k mg\cos\theta = ma$$

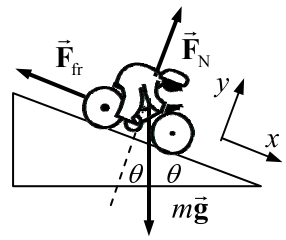
$$a = g\frac{(1-\sin\theta-\mu_k\cos\theta)}{2} = (9.8\,\mathrm{m/s^2})\frac{(1-\sin 25^\circ - 0.15\cos 25^\circ)}{2} = \boxed{2.2\,\mathrm{m/s^2}}$$

(*b*) To have an acceleration of zero, the expression for the acceleration must be zero.

$$a = g\frac{(1-\sin\theta-\mu_k\cos\theta)}{2} = 0 \;\rightarrow\; 1-\sin\theta-\mu_k\cos\theta = 0 \;\rightarrow$$

$$\mu_k = \frac{1-\sin\theta}{\cos\theta} = \frac{1-\sin 25^\circ}{\cos 25^\circ} = \boxed{0.64}$$

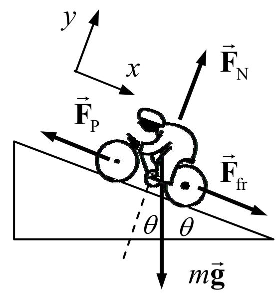
65. Consider a free-body diagram for the cyclist coasting downhill at a constant speed. Since there is no acceleration, the net force in each direction must be zero. Write Newton's 2nd law for the x direction.



$$\sum F_x = mg\sin\theta - F_{fr} = 0 \;\rightarrow\; F_{fr} = mg\sin\theta$$

This establishes the size of the air friction force at 6.0 km/h, and so can be used in the next part.

Now consider a free-body diagram for the cyclist climbing the hill. F_P is the force pushing the cyclist uphill. Again, write Newton's 2nd law for the x direction, with a net force of 0.



$$\sum F_x = F_{fr} + mg\sin\theta - F_P = 0 \;\rightarrow$$

$$F_P = F_{fr} + mg\sin\theta = 2mg\sin\theta$$

$$= 2(65\text{ kg})(9.8\,\mathrm{m/s^2})(\sin 6.0^\circ) = \boxed{1.3\times10^2\,\mathrm{N}}$$

66. The average acceleration of the blood is given by $a = \frac{v-v_0}{t} = \frac{0.35\,\mathrm{m/s} - 0.25\,\mathrm{m/s}}{0.10\text{ s}} = 1.0\,\mathrm{m/s^2}$.

Thus the net force on the blood, exerted by the heart, would be

$$F = ma = (20\times10^{-3}\,\mathrm{kg})(1.0\,\mathrm{m/s^2}) = \boxed{0.020\text{ N}}.$$

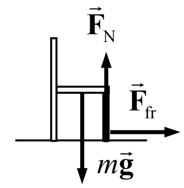
67. The acceleration of a person having a 30 "g" deceleration is $a = (30\,\text{"}g\text{"})\left(\frac{9.8\,\mathrm{m/s^2}}{\text{"}g\text{"}}\right) = 290\,\mathrm{m/s^2}$.

The average force causing that acceleration is $F = ma = (70\text{ kg})(290\,\mathrm{m/s^2}) = \boxed{2.1\times10^4\,\mathrm{N}}$. Since the person is undergoing a deceleration, the acceleration and force would both be directed opposite to the direction of motion. Use Eq. 2-11c to find the distance traveled during the deceleration. Take the initial velocity to be in the positive direction, so that the acceleration will have a negative value, and the final velocity will be 0.

$$v_0 = (100\,\mathrm{km/h})\left(\frac{1\,\mathrm{m/s}}{3.6\,\mathrm{km/h}}\right) = 27.78\,\mathrm{m/s}$$

$$v^2 - v_0^2 = 2a(x-x_0) \;\rightarrow\; (x-x_0) = \frac{v^2-v_0^2}{2a} = \frac{0-(27.78\,\mathrm{m/s})^2}{2(-290\,\mathrm{m/s^2})} = \boxed{1.3\text{ m}}$$

68. (*a*) Assume that the earthquake is moving the Earth to the right. If an object is to "hold its place", then the object must also be accelerating to the right with the Earth. The force that will accelerate that object will be the static frictional force, which would also have to be to the right. If the force were not large enough, the Earth would move out from under the chair somewhat, giving the appearance that the chair were being "thrown" to the left. Consider the free-body diagram shown for a chair on the floor. It is apparent that the normal force is equal to the weight since there is no motion in the vertical direction. Newton's 2nd law says that $F_{\text{fr}} = ma$.



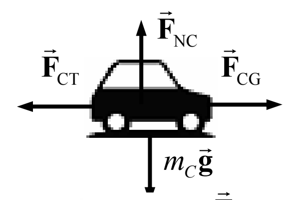
We also assume that the chair is just on the verge of slipping, which means that the static frictional force has its maximum value of $F_{\text{fr}} = \mu_s F_{\text{N}} = \mu_s mg$. Equate the two expressions for the frictional force to find the coefficient of friction.

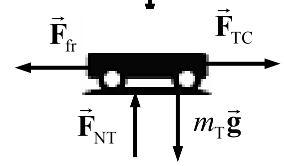
$$ma = \mu_s mg \quad \rightarrow \quad \boxed{\mu_s = a/g}$$

If the static coefficient is larger than this, then there will be a larger maximum frictional force, and the static frictional force will be more than sufficient to hold the chair in place on the floor.

(*b*) For the 1989 quake, $\dfrac{a}{g} = \dfrac{4.0\,\text{m/s}^2}{9.8\,\text{m/s}^2} = 0.41$. Since $\mu_s = 0.25$, $\boxed{\text{the chair would slide}}$.

$\boxed{69.}$ We draw three free-body diagrams – one for the car, one for the trailer, and then "add" them for the combination of car and trailer. Note that since the car pushes against the ground, the ground will push against the car with an equal but oppositely directed force. $\vec{\mathbf{F}}_{\text{CG}}$ is the force on the car due to the ground, $\vec{\mathbf{F}}_{\text{TC}}$ is the force on the trailer due to the car, and $\vec{\mathbf{F}}_{\text{CT}}$ is the force on the car due to the trailer. Note that by Newton's 3rd law, $\left|\vec{\mathbf{F}}_{\text{CT}}\right| = \left|\vec{\mathbf{F}}_{\text{TC}}\right|$.

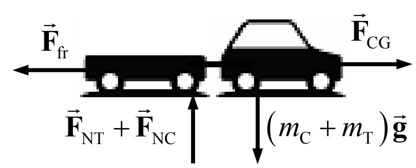




From consideration of the vertical forces in the individual free-body diagrams, it is apparent that the normal force on each object is equal to its weight. This leads to the conclusion that

$$F_{\text{fr}} = \mu_k F_{\text{NT}} = \mu_k m_{\text{T}} g = (0.15)(450\text{ kg})(9.8\,\text{m/s}^2) = 660\text{ N}.$$

Now consider the combined free-body diagram. Write Newton's 2nd law for the horizontal direction, This allows the calculation of the acceleration of the system.



$$\sum F = F_{\text{CG}} - F_{\text{fr}} = (m_{\text{C}} + m_{\text{T}})a \quad \rightarrow$$

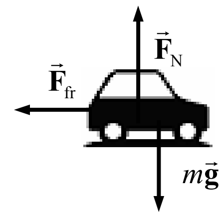
$$a = \frac{F_{\text{CG}} - F_{\text{fr}}}{m_{\text{C}} + m_{\text{T}}} = \frac{3800\text{ N} - 660\text{ N}}{1600\text{ kg}} = 1.9625\,\text{m/s}^2$$

Finally, consider the free-body diagram for the trailer alone. Again write Newton's 2nd law for the horizontal direction, and solve for F_{TC}.

$$\sum F = F_{\text{TC}} - F_{\text{fr}} = m_{\text{T}} a \quad \rightarrow$$

$$F_{\text{TC}} = F_{\text{fr}} + m_{\text{T}} a = 660\text{ N} + (450\text{ kg})(1.9625\,\text{m/s}^2) = \boxed{1.54\times10^3\,\text{N}}$$

70. Assume that kinetic friction is the net force causing the deceleration. See the free-body diagram for the car, assuming that the right is the positive direction, and the direction of motion of the skidding car. Since there is no acceleration in the vertical direction, and so $F_N = mg$. Applying Newton's 2nd law to the x direction gives



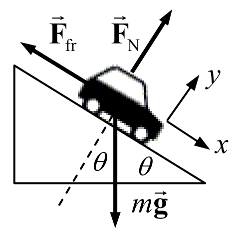
$$\sum F = -F_f = ma \rightarrow -\mu_k F_N = -\mu_k mg = ma \rightarrow a = -\mu_k g.$$

Use Eq. 2-11c to determine the initial speed of the car, with the final speed of the car being zero.

$$v^2 - v_0^2 = 2a(x - x_0) \rightarrow$$

$$v_0 = \sqrt{v^2 - 2a(x - x_0)} = \sqrt{0 - 2(-\mu_k g)(x - x_0)} = \sqrt{2(0.8)(9.8\,\text{m/s}^2)(72\text{ m})} = \boxed{34\,\text{m/s}}$$

71. We include friction from the start, and then for the no-friction result, set the coefficient of friction equal to 0. Consider a free-body diagram for the car on the hill. Write Newton's 2nd law for both directions. Note that the net force on the y direction will be zero, since there is no acceleration in the y direction.



$$\sum F_y = F_N - mg\cos\theta = 0 \rightarrow F_N = mg\cos\theta$$

$$\sum F_x = mg\sin\theta - F_{fr} = ma \rightarrow$$

$$a = g\sin\theta - \frac{F_{fr}}{m} = g\sin\theta - \frac{\mu_k mg\cos\theta}{m} = g(\sin\theta - \mu_k\cos\theta)$$

Use Eq. 2-11c to determine the final velocity, assuming that the car starts from rest.

$$v^2 - v_0^2 = 2a(x - x_0) \rightarrow v = \sqrt{0 + 2a(x - x_0)} = \sqrt{2g(x - x_0)(\sin\theta - \mu_k\cos\theta)}$$

The angle is given by $\sin\theta = 1/4 \rightarrow \theta = \sin^{-1} 0.25 = 14.5^\circ$

(*a*) $\mu_k = 0 \rightarrow v = \sqrt{2g(x - x_0)x\sin\theta} = \sqrt{2(9.8\,\text{m/s}^2)(55\text{ m})\sin 14.5^\circ} = \boxed{16\,\text{m/s}}$

(*b*) $\mu_k = 0.10 \rightarrow v = \sqrt{2(9.8\,\text{m/s}^2)(55\text{ m})(\sin 14.5^\circ - 0.10\cos 14.5^\circ)} = \boxed{13\,\text{m/s}}$

72. See the free-body diagram for the falling purse. Assume that down is the positive direction, and that the air resistance force $\vec{\mathbf{F}}_{fr}$ is constant. Write Newton's 2nd law for the vertical direction.

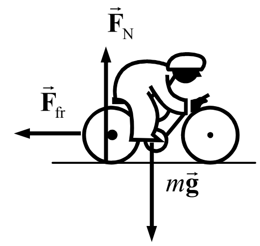
$$\sum F = mg - F_{fr} = ma \rightarrow F_{fr} = m(g - a)$$

Now obtain an expression for the acceleration from Eq. 2-11c with $v_0 = 0$, and substitute back into the friction force.

$$v^2 - v_0^2 = 2a(x - x_0) \rightarrow a = \frac{v^2}{2(x - x_0)}$$

$$F_f = m\left(g - \frac{v^2}{2(x - x_0)}\right) = (2.0\text{ kg})\left(9.8\,\text{m/s}^2 - \frac{(29\,\text{m/s})^2}{2(55\text{ m})}\right) = \boxed{4.3\text{ N}}$$

73. Consider the free-body diagram for the cyclist in the mud, assuming that the cyclist is traveling to the right. It is apparent that $F_N = mg$ since there is no vertical acceleration. Write Newton's 2nd law for the horizontal direction, positive to the right.



$$\sum F_x = -F_{fr} = ma \rightarrow -\mu_k mg = ma \rightarrow a = -\mu_k g$$

Use Eq. 2-11c to determine the distance the cyclist could travel in the mud before coming to rest.

$$v^2 - v_0^2 = 2a(x - x_0) \rightarrow (x - x_0) = \frac{v^2 - v_0^2}{2a} = \frac{-v_0^2}{-2\mu_k g} = \frac{(12\,\text{m/s})^2}{2(0.60)(9.8\,\text{m/s}^2)} = 12\text{ m}$$

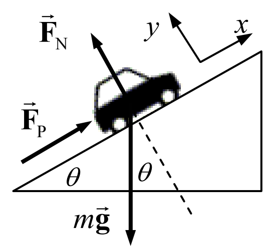
Since there is only 11 m of mud, $\boxed{\text{the cyclist will emerge from the mud.}}$ The speed upon emerging is found from Eq. 2-11c.

$$v^2 - v_0^2 = 2a(x - x_0) \rightarrow$$

$$v = \sqrt{v_0^2 + 2a(x - x_0)} = \sqrt{v_i^2 - 2\mu_k g(x - x_0)} = \sqrt{(12\,\text{m/s})^2 - 2(0.60)(9.8\,\text{m/s}^2)(11\text{ m})}$$

$$= \boxed{3.8\,\text{m/s}}$$

74. The given data can be used to calculate the force with which the road pushes against the car, which in turn is equal in magnitude to the force the car pushes against the road. The acceleration of the car on level ground is found from Eq. 2-11a.



$$v - v_0 = at \rightarrow a = \frac{v - v_0}{t} = \frac{21\,\text{m/s} - 0}{14.0\text{ s}} = 1.50\,\text{m/s}^2$$

The force pushing the car in order to have this acceleration is found from Newton's 2nd law.

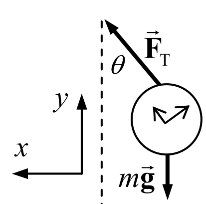
$$F_P = ma = (1100\text{ kg})(1.50\,\text{m/s}^2) = 1650\text{ N}$$

We assume that this is the force pushing the car on the incline as well. Consider a free-body diagram for the car climbing the hill. We assume that the car will have a constant speed on the maximum incline. Write Newton's 2nd law for the *x* direction, with a net force of zero since the car is not accelerating.

$$\sum F_x = F_P - mg\sin\theta = 0 \rightarrow \sin\theta = \frac{F_P}{mg}$$

$$\theta = \sin^{-1}\frac{F_P}{mg} = \sin^{-1}\frac{1650\text{ N}}{(1100\text{ kg})(9.8\,\text{m/s}^2)} = \boxed{8.8^\circ}$$

75. Consider the free-body diagram for the watch. Write Newton's 2nd law for both the *x* and *y* directions. Note that the net force in the *y* direction is 0 because there is no acceleration in the *y* direction.



$$\sum F_y = F_T\cos\theta - mg = 0 \rightarrow F_T = \frac{mg}{\cos\theta}$$

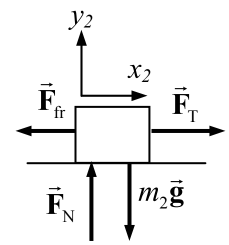
$$\sum F_x = F_T\sin\theta = ma \rightarrow \frac{mg}{\cos\theta}\sin\theta = ma$$

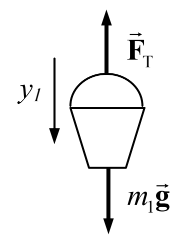
$$a = g\tan\theta = (9.8\,\text{m/s}^2)\tan 25^\circ = 4.6\,\text{m/s}^2$$

Use Eq. 2-11a with $v_0 = 0$ to find the final velocity (takeoff speed).

$$v - v_0 = at \quad \to \quad v = v_0 + at = 0 + \left(4.6\,\text{m/s}^2\right)\left(18\ \text{s}\right) = \boxed{82\,\text{m/s}}$$

$\boxed{76.}$ (*a*) Consider the free-body diagrams for both objects, initially stationary. As sand is added, the tension will increase, and the force of static friction on the block will increase until it reaches its maximum of $F_{\text{fr}} = \mu_s F_{\text{N}}$. Then the system will start to move. Write Newton's 2nd law for each object, when the static frictional force is at its maximum, but the objects are still stationary.





$$\sum F_{y\text{ bucket}} = m_1 g - F_{\text{T}} = 0 \quad \to \quad F_{\text{T}} = m_1 g$$

$$\sum F_{y\text{ block}} = F_{\text{N}} - m_2 g = 0 \quad \to \quad F_{\text{N}} = m_2 g$$

$$\sum F_{x\text{ block}} = F_{\text{T}} - F_{\text{fr}} = 0 \quad \to \quad F_{\text{T}} = F_{\text{fr}}$$

Equate the two expressions for tension, and substitute in the expression for the normal force to find the masses.

$$m_1 g = F_{\text{fr}} \quad \to \quad m_1 g = \mu_s F_{\text{N}} = \mu_s m_2 g \quad \to$$

$$m_1 = \mu_s m_2 = (0.450)(28.0\ \text{kg}) = 12.6\ \text{kg}$$

Thus $12.6\ \text{kg} - 1.35\ \text{kg} = 11.25 = \boxed{11.3\ \text{kg}}$ of sand was added.

(*b*) The same free-body diagrams can be used, but now the objects will accelerate. Since they are tied together, $a_{y1} = a_{x2} = a$. The frictional force is now kinetic friction, given by $F_{\text{fr}} = \mu_k F_{\text{N}} = \mu_k m_2 g$. Write Newton's 2nd laws for the objects in the direction of their acceleration.

$$\sum F_{y\text{ bucket}} = m_1 g - F_{\text{T}} = m_1 a \quad \to \quad F_{\text{T}} = m_1 g - m_1 a$$

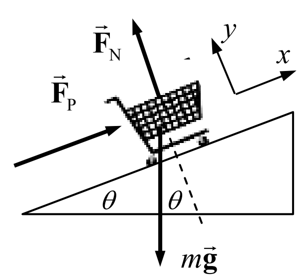
$$\sum F_{x\text{ block}} = F_{\text{T}} - F_{\text{fr}} = m_2 a \quad \to \quad F_{\text{T}} = F_{\text{fr}} + m_2 a$$

Equate the two expressions for tension, and solve for the acceleration.

$$m_1 g - m_1 a = \mu_k m_2 g + m_2 a$$

$$a = g\frac{\left(m_1 - \mu_k m_2\right)}{\left(m_1 + m_2\right)} = \left(9.80\,\text{m/s}^2\right)\frac{\left(12.6\text{kg} - (0.320)(28.0\text{kg})\right)}{\left(12.6\text{kg} + 28.0\text{kg}\right)} = \boxed{0.88\,\text{m/s}^2}$$

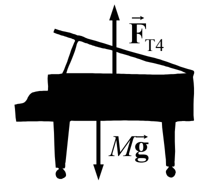
77. Consider a free-body diagram for a grocery cart being pushed up an incline. Assuming that the cart is not accelerating, we write Newton's 2nd law for the x direction.



$$\sum F_x = F_{\text{P}} - mg\sin\theta = 0 \quad \to \quad \sin\theta = \frac{F_{\text{P}}}{mg}$$

$$\theta = \sin^{-1}\frac{F_{\text{P}}}{mg} = \sin^{-1}\frac{20\ \text{N}}{(20\ \text{kg})\left(9.8\,\text{m/s}^2\right)} = \boxed{5.9^\circ}$$

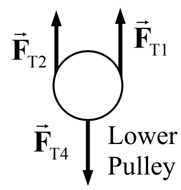
78. (*a*) To find the minimum force, assume that the piano is moving with a constant velocity. Since the piano is not accelerating, $F_{T4} = Mg$. For the lower pulley, since the tension in a rope is the same throughout, and since the pulley is not accelerating, it is seen that

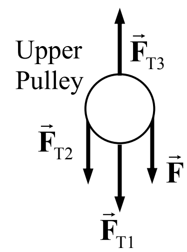


$$F_{T1} + F_{T2} = 2F_{T1} = Mg \quad \rightarrow \quad F_{T1} = F_{T2} = Mg/2 .$$

It also can be seen that since $F = F_{T2}$, that $\boxed{F = Mg/2}$.

(*b*) Draw a free-body diagram for the upper pulley. From that diagram, we see that



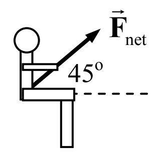


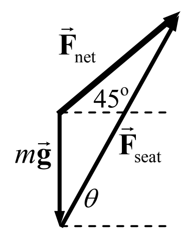
$$F_{T3} = F_{T1} + F_{T2} + F = \frac{3Mg}{2}$$

To summarize:

$$\boxed{F_{T1} = F_{T2} = Mg/2 \quad F_{T3} = 3Mg/2 \quad F_{T4} = Mg}$$

79. The acceleration of the pilot will be the same as that of the plane, since the pilot is at rest with respect to the plane. Consider first a free-body diagram of the pilot, showing only the net force. By Newton's 2nd law, the net force MUST point in the direction of the acceleration, and its magnitude is ma. That net force is the sum of ALL forces on the pilot. If we assume that the force of gravity and the force of the cockpit seat on the pilot are the only forces on the pilot, then in terms of vectors, $\vec{F}_{net} = m\vec{g} + \vec{F}_{seat} = m\vec{a}$. Solve this equation for the force of the seat to find $\vec{F}_{seat} = \vec{F}_{net} - m\vec{g} = m\vec{a} - m\vec{g}$. A vector diagram of that equation is as shown.





Solve for the force of the seat on the pilot using components.

$$F_{x\text{ seat}} = F_{x\text{ net}} = ma\cos 45^\circ = (75\text{ kg})(3.5\,\text{m/s}^2)\cos 45^\circ = 180\text{ N}$$

$$F_{y\text{ seat}} = mg + F_{y\text{ net}} = mg + ma\sin 45^\circ$$

$$= (75\text{ kg})(9.8\,\text{m/s}^2) + (75\text{ kg})(3.5\,\text{m/s}^2)\cos 45^\circ = 920\text{ N}$$

The magnitude of the cockpit seat force is

$$F = \sqrt{F_{x\text{ seat}}^2 + F_{y\text{ seat}}^2} = \sqrt{(180\text{ N})^2 + (920\text{ N})^2} = \boxed{940\text{ N}}$$

The angle of the cockpit seat force is

$$\theta = \tan^{-1}\frac{F_{y\text{ seat}}}{F_{x\text{ seat}}} = \tan^{-1}\frac{920\text{ N}}{180\text{ N}} = \boxed{79^\circ} \text{ above the horizontal.}$$

80. The initial speed is $v_i = (45\,\text{km/h})\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 12.5\,\text{m/s}$. Use Eq. 2-11a to find the deceleration of the child.

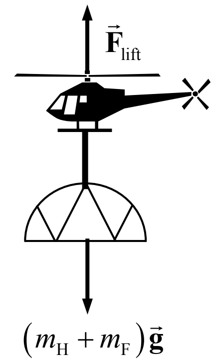
$$v - v_0 = at \quad \rightarrow \quad a = \frac{v - v_0}{t} = \frac{0 - 12.5\,\text{m/s}}{0.20\text{ s}} = -62.5\,\text{m/s}^2 .$$

The net force on the child is given by Newton's 2nd law.

$$F_{net} = ma = (12\text{ kg})(-62.5\,\text{m/s}^2) = \boxed{-7.5\times 10^2\,\text{N}}, \text{ opposite to the velocity}$$

We also assumed that friction between the seat and child is zero, and we assumed that the bottom of the seat is horizontal. If friction existed or if the seat was tilted back, then the force that the straps would have to apply would be less.

81 (*a*) The helicopter and frame will both have the same acceleration, and so can be treated as one object if no information about internal forces (like the cable tension) is needed. A free-body diagram for the helicopter-frame combination is shown. Write Newton's 2nd law for the combination, calling UP the positive direction.

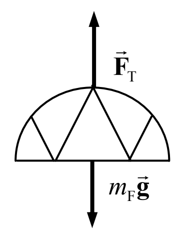


$$\sum F = F_{\text{lift}} - (m_{\text{H}}+m_{\text{F}})g = (m_{\text{H}}+m_{\text{F}})a \quad \rightarrow$$

$$F_{\text{lift}} = (m_{\text{H}}+m_{\text{F}})(g+a) = (7650\text{ kg}+1250\text{ kg})(9.80\,\text{m/s}^2+0.80\,\text{m/s}^2)$$

$$= \boxed{9.43\times10^4\,\text{N}}$$

(*b*) Now draw a free-body diagram for the frame alone, in order to find the tension in the cable. Again use Newton's 2nd law.



$$\sum F = F_{\text{T}} - m_{\text{F}}g = m_{\text{F}}a \quad \rightarrow$$

$$F_{\text{T}} = m_{\text{F}}(g+a) = (1250\text{ kg})(9.80\,\text{m/s}^2+0.80\,\text{m/s}^2) = \boxed{1.33\times10^4\,\text{N}}$$

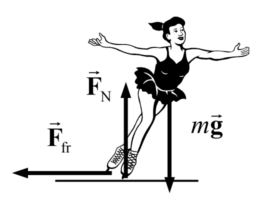
(*c*) The tension in the cable is the same at both ends, and so the cable exerts a force of $\boxed{1.33\times10^4\,\text{N}}$ downward on the helicopter.

82. (*a*) We assume that the maximum horizontal force occurs when the train is moving very slowly, and so the air resistance is negligible. Thus the maximum acceleration is given by

$$a_{\text{max}} = \frac{F_{\text{max}}}{m} = \frac{4.0\times10^5\,\text{N}}{6.6\times10^5\,\text{kg}} = \boxed{0.61\,\text{m/s}^2}.$$

(*b*) At top speed, we assume that the train is moving at constant velocity. Therefore the net force on the train is 0, and so the air resistance must be of the same magnitude as the horizontal pushing force, which is $\boxed{1.5\times10^5\,\text{N}}$.

83. Consider the free-body diagram for the decelerating skater, moving to the right. It is apparent that $F_{\text{N}} = mg$ since there is no acceleration in the vertical direction. From Newton's 2nd law in the horizontal direction, we have



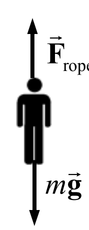
$$\sum F = F_{\text{fr}} = ma \quad \rightarrow \quad -\mu_k mg = ma \quad \rightarrow \quad a = -\mu_k g$$

Now use Eq. 2-11c to find the starting speed.

$$v^2 - v_0^2 = 2a(x-x_0) \quad \rightarrow$$

$$v_0 = \sqrt{v^2 - 2a(x-x_0)} = \sqrt{0+2\mu_k g(x-x_0)} = \sqrt{2(0.10)(9.8\,\text{m/s}^2)(75\text{ m})} = \boxed{12\,\text{m/s}}$$

84. First calculate Karen's speed from falling. Let the downward direction be positive, and use Eq. 2-11c with $v_0 = 0$.



$$v^2 - v_0^2 = 2a(y-y_0) \quad \rightarrow \quad v = \sqrt{0+2a(y-y_0)} = \sqrt{2(9.8\,\text{m/s}^2)(2.0\text{ m})} = 6.26\,\text{m/s}$$

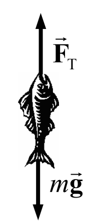
Now calculate the average acceleration as the rope stops Karen, again using Eq. 2-11c, with down as positive.

$$v^2 - v_0^2 = 2a(y-y_0) \quad \rightarrow \quad a = \frac{v^2-v_0^2}{2(y-y_0)} = \frac{0-(6.26\,\text{m/s})^2}{2(1.0\text{ m})} = -19.6\,\text{m/s}^2$$

The negative sign indicates that the acceleration is upward. Since this is her acceleration, the net force on Karen is given by Newton's 2nd law, $F_{\text{net}} = ma$. That net force will also be upward. Now consider the free-body diagram shown of Karen as she decelerates. Call DOWN the positive direction, and Newton's 2nd law says that $F_{\text{net}} = ma = mg - F_{\text{rope}} \rightarrow F_{\text{rope}} = mg - ma$. The ratio of this force to Karen's weight would be $\dfrac{F_{\text{rope}}}{mg} = \dfrac{mg - ma}{g} = 1.0 - \dfrac{a}{g} = 1.0 - \dfrac{-19.6\,\text{m/s}^2}{9.8\,\text{m/s}^2} = 3.0$. Thus the rope pulls upward on Karen with an average force of $\boxed{\text{3.0 times her weight}}$.

A completely analogous calculation for Bill gives the same speed after the 2.0 m fall, but since he stops over a distance of 0.30 m, his acceleration is –65 m/s^2, and the rope pulls upward on Bill with an average force of $\boxed{\text{7.7 times his weight}}$. Thus $\boxed{\text{Bill is more likely to get hurt}}$ in the fall.

85. See the free-body diagram for the fish being pulled upward vertically. From Newton's 2nd law, calling the upward direction positive, we have



$$\sum F_y = F_{\text{T}} - mg = ma \quad \rightarrow \quad F_{\text{T}} = m(g + a)$$

(*a*) If the fish has a constant speed, then its acceleration is zero, and so $F_{\text{T}} = mg$. Thus the heaviest fish that could be pulled from the water in this case is $\boxed{45\text{ N }(10\text{ lb})}$.

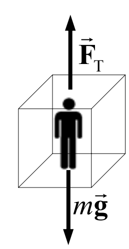
(*b*) If the fish has an acceleration of 2.0 m/s^2, and F_{T} is at its maximum of 45 N, then solve the equation for the mass of the fish.

$$m = \frac{F_{\text{T}}}{g + a} = \frac{45\text{ N}}{9.8\,\text{m/s}^2 + 2.0\,\text{m/s}^2} = 3.8\text{ kg} \quad \rightarrow$$

$$mg = (3.8\text{ kg})(9.8\,\text{m/s}^2) = \boxed{37\text{ N }(\approx 8.4\text{ lb})}$$

(*c*) It is not possible to land a 15-lb fish using 10-lb line, if you have to lift the fish vertically. If the fish were reeled in while still in the water, and then a net used to remove the fish from the water, it might still be caught with the 10-lb line.

86. Choose downward to be positive. The elevator's acceleration is calculated by Eq. 2-11c.



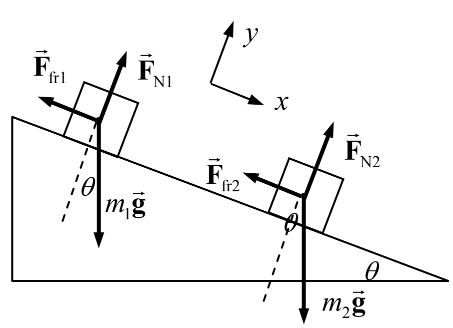
$$v^2 - v_0^2 = 2a(y - y_0) \quad \rightarrow \quad a = \frac{v^2 - v_0^2}{2(y - y_0)} = \frac{0 - (3.5\,\text{m/s})^2}{2(2.6\text{ m})} = -2.356\,\text{m/s}^2$$

See the free-body diagram of the elevator. Write Newton's 2nd law for the elevator.

$$\sum F_y = mg - F_{\text{T}} = ma$$

$$F_{\text{T}} = m(g - a) = (1300\text{ kg})(9.80\,\text{m/s}^2 - -2.356\,\text{m/s}^2) = \boxed{1.58 \times 10^4\text{ N}}$$

87. (*a*) Draw a free-body diagram for each block, with no connecting tension. Because of the similarity of the free-body diagrams, we shall just analyze block 1. Write Newton's 2nd law in both the *x* and *y* directions. The net force in the *y* direction is zero, because there is no acceleration in the *y* direction.



$$\sum F_{y1} = F_{\text{N1}} - m_1 g\cos\theta = 0 \quad \rightarrow \quad F_{\text{N1}} = m_1 g\cos\theta$$

$$\sum F_{x1} = m_1 g\sin\theta - F_{\text{fr1}} = m_1 a_1 \quad \rightarrow$$

$$a_1 = \frac{m_1 g \sin\theta - F_{\text{fr1}}}{m_1} = \frac{m_1 g \sin\theta - \mu_k m_1 g \cos\theta}{m_1} = g\left(\sin\theta - \mu_1 \cos\theta\right)$$

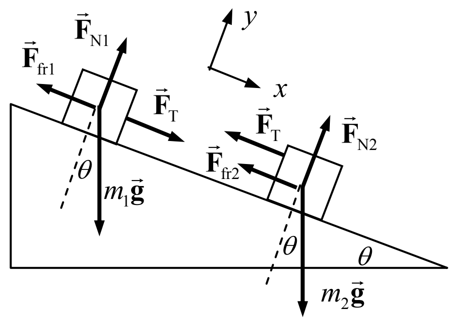
$$= \left(9.8\,\text{m/s}^2\right)\left(\sin 30^\circ - 0.10\cos 30^\circ\right) = \boxed{4.1\,\text{m/s}^2}$$

The same analysis for block 2 would give

$$a_2 = g\left(\sin\theta - \mu_2\cos\theta\right) = \left(9.8\,\text{m/s}^2\right)\left(\sin 30^\circ - 0.20\cos 30^\circ\right) = \boxed{3.2\,\text{m/s}^2}$$

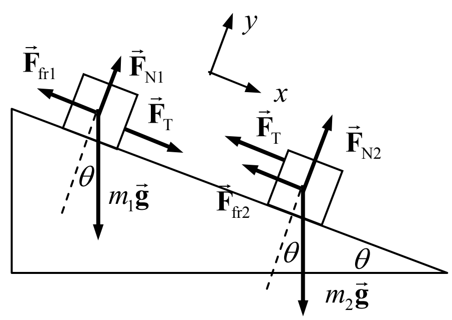
Since $a_2 < a_1$, if both blocks were released from rest, block # 1 would "gain" on block 2.

(*b*) Now let the rope tension be present. Before writing equations, consider that without the tension, $a_1 > a_2$. In the free-body diagram shown, m_1 now has even more force accelerating down the plane because of the addition of the tension force, which means m_1 has an even larger acceleration than before. And m_2 has less force accelerating it down the plane because of the addition of the tension force. Thus m_2 has a smaller acceleration than before. And so in any amount of time considered, m_1 will move more distance down the plane upon release than block m_2. The cord will go slack almost immediately after the blocks are released, and the blocks revert to the original free-body diagram. The conclusion is that the accelerations in this part of the problem are the same as they would be in part (*a*):



$$\boxed{a_1 = 4.1\,\text{m/s}^2\ ;\ a_2 = 3.2\,\text{m/s}^2}.$$

(*c*) Now reverse the position of the masses. Write Newton's 2nd law for each block, and assume that they have the same acceleration. The *y* equations and frictional forces are unchanged from the analysis in part (*a*), so we only write the *x* equations. After writing them, add them together (to eliminate the tension) and solve for the acceleration.



$$\sum F_{x1} = m_1 g\sin\theta - F_{\text{fr1}} - F_{\text{T}} = m_1 a$$

$$\sum F_{x2} = m_2 g\sin\theta - F_{\text{fr2}} + F_{\text{T}} = m_2 a$$

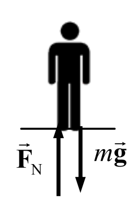
$$\left(m_1 + m_2\right) g\sin\theta - F_{\text{fr1}} - F_{\text{fr2}} = \left(m_1 + m_2\right) a$$

$$a = \frac{\left(m_1 + m_2\right) g\sin\theta - \mu_1 m_1 g\cos\theta - \mu_2 m_2 g\cos\theta}{\left(m_1 + m_2\right)} = g\left[\sin\theta - \frac{\mu_1 m_1 + \mu_2 m_2}{m_1 + m_2}\cos\theta\right]$$

$$= \left(9.8\,\text{m/s}^2\right)\left[\sin 30^\circ - \frac{(0.10)(1.0\text{ kg}) + (0.20)(2.0\text{ kg})}{3.0\text{ kg}}\cos 30^\circ\right] = \boxed{3.5\,\text{m/s}^2}$$

88. See the free-body diagram of the person in the elevator. The scale will read the normal force. Choose upward to be positive. From Newton's 2nd law,

$$\sum F = F_{\text{N}} - mg = ma \quad\rightarrow\quad F_{\text{N}} = m\left(g + a\right)$$



(*a*, *b*, *c*) If the elevator is either at rest or moving with a constant vertical speed, either up or down, the acceleration is zero, and so

$$F_N = mg = (75.0\ \text{kg})(9.80\ \text{m/s}^2) = \boxed{7.35\times10^2\ \text{N}} \quad m = \frac{F_N}{g} = \boxed{75.0\ \text{kg}}$$

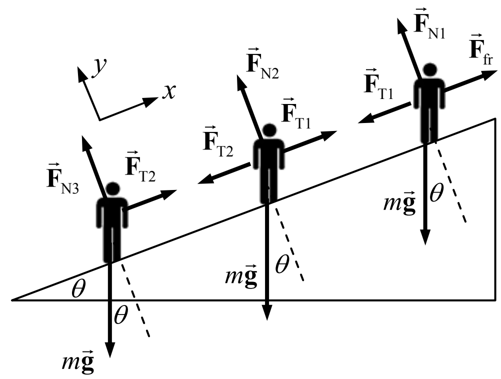
(*d*) When accelerating upward, the acceleration is $+3.0\ \text{m/s}^2$, and so

$$F_N = m(g+a) = (75.0\ \text{kg})(12.8\ \text{m/s}^2) = \boxed{9.60\times10^2\ \text{N}} \quad m = \frac{F_N}{g} = \boxed{98.0\ \text{kg}}$$

(*e*) When accelerating downward, the acceleration is $-3.0\ \text{m/s}^2$, and so

$$F_N = m(g+a) = (75.0\ \text{kg})(6.80\ \text{m/s}^2) = \boxed{5.10\times10^2\ \text{N}} \quad m = \frac{F_N}{g} = \boxed{52.0\ \text{kg}}$$

89. Since the climbers are on ice, the frictional force for the lower two climbers is negligible. Consider the free-body diagram as shown. Note that all the masses are the same. Write Newton's 2nd law in the *x* direction for the lowest climber, assuming he is at rest.



$$\sum F_x = F_{T2} - mg\sin\theta = 0$$

$$F_{T2} = mg\sin\theta = (75\ \text{kg})(9.8\ \text{m/s}^2)\sin 21.0^\circ = \boxed{2.6\times10^2\ \text{N}}$$

Write Newton's 2nd law in the *x* direction for the middle climber, assuming he is at rest.

$$\sum F_x = F_{T1} - F_{T2} - mg\sin\theta = 0 \quad\rightarrow\quad F_{T1} = F_{T2} + mg\sin\theta = 2F_{T2} = \boxed{5.3\times10^2\ \text{N}}$$