SOLUTION
a. The conservation of mechanical energy states that

$$\tfrac{1}{2}mv_B^2 + mgh_B = \tfrac{1}{2}mv_A^2 + mgh_A \qquad (6.9b)$$

Solving for the speed v_B at B gives

$$v_B = \sqrt{v_A^2 + 2g(h_A - h_B)} = \sqrt{(0\text{ m/s})^2 + 2(9.80\text{ m/s}^2)(4.5\text{ m} - 1.5\text{ m})} = \boxed{7.7\text{ m/s}}$$

b. The speed of the heavier box is the same as that of the lighter box: $\boxed{7.7\text{ m/s}}$.

c. The ratio of the kinetic energies is

$$\frac{(\text{KE}_B)_{\text{heavier box}}}{(\text{KE}_B)_{\text{lighter box}}} = \frac{\left(\tfrac{1}{2}mv_B^2\right)_{\text{heavier box}}}{\left(\tfrac{1}{2}mv_B^2\right)_{\text{lighter box}}} = \frac{m_{\text{heavier box}}}{m_{\text{lighter box}}} = \frac{44\text{ kg}}{11\text{ kg}} = \boxed{4.0}$$

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39. ***REASONING*** We can find the landing speed v_f from the final kinetic energy KE_f, since $\text{KE}_f = \tfrac{1}{2}mv_f^2$. Furthermore, we are ignoring air resistance, so the conservation of mechanical energy applies. This principle states that the mechanical energy with which the pebble is initially launched is also the mechanical energy with which it finally strikes the ground. Mechanical energy is kinetic energy plus gravitational potential energy. With respect to potential energy we will use ground level as the zero level for measuring heights. The pebble initially has kinetic and potential energies. When it strikes the ground, however, the pebble has only kinetic energy, its potential energy having been converted into kinetic energy. It does not matter how the pebble is launched, because only the vertical height determines the gravitational potential energy. Thus, in each of the three parts of the problem the same amount of potential energy is converted into kinetic energy. As a result, the speed that we will calculate from the final kinetic energy will be the same in parts (a), (b), and (c).

SOLUTION
a. Applying the conservation of mechanical energy in the form of Equation 6.9b, we have

$$\underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{\substack{\text{Final mechanical energy}\\ \text{at ground level}}} = \underbrace{\tfrac{1}{2}mv_0^2 + mgh_0}_{\substack{\text{Initial mechanical energy}\\ \text{at top of building}}}$$

Solving for the final speed gives

$$v_f = \sqrt{v_0^2 + 2g(h_0 - h_f)} = \sqrt{(14.0\text{ m/s})^2 + 2(9.80\text{ m/s}^2)[(31.0\text{ m}) - (0\text{ m})]} = \boxed{28.3\text{ m/s}}$$

b. The calculation and answer are the same as in part (a).

c. The calculation and answer are the same as in part (a).

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40. ***REASONING*** The distance h in the drawing in the text is the difference between the skateboarder's final and initial heights (measured, for example, with respect to the ground), or $h = h_f - h_0$. The difference in the heights can be determined by using the conservation of mechanical energy. This conservation law is applicable because nonconservative forces are negligible, so the work done by them is zero ($W_{nc} = 0$ J). Thus, the skateboarder's final total mechanical energy E_f is equal to his initial total mechanical energy E_0:

$$\underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{E_f} = \underbrace{\tfrac{1}{2}mv_0^2 + mgh_0}_{E_0} \qquad (6.9b)$$

Solving Equation 6.9b for $h_f - h_0$, we find that

$$\underbrace{h_f - h_0}_{h} = \frac{\tfrac{1}{2}v_0^2 - \tfrac{1}{2}v_f^2}{g}$$

SOLUTION Using the fact that $v_0 = 5.4$ m/s and $v_f = 0$ m/s (since the skateboarder comes to a momentary rest), the distance h is

$$h = \frac{\tfrac{1}{2}v_0^2 - \tfrac{1}{2}v_f^2}{g} = \frac{\tfrac{1}{2}(5.4\text{ m/s})^2 - \tfrac{1}{2}(0\text{ m/s})^2}{9.80\text{ m/s}^2} = \boxed{1.5\text{ m}}$$

---

41. ***REASONING*** Since air resistance is being neglected, the only force that acts on the golf ball is the conservative gravitational force (its weight). Since the maximum height of the trajectory and the initial speed of the ball are known, the conservation of mechanical energy can be used to find the kinetic energy of the ball at the top of the highest point. The conservation of mechanical energy can also be used to find the speed of the ball when it is 8.0 m below its highest point.

SOLUTION
a. The conservation of mechanical energy, Equation 6.9b, states that

$$\underbrace{\tfrac{1}{2}mv_f^2}_{\text{KE}_f} + mgh_f = \tfrac{1}{2}mv_0^2 + mgh_0$$

Solving this equation for the final kinetic energy, KE_f, yields

$$KE_f = \tfrac{1}{2}mv_0^2 + mg\left(h_0 - h_f\right)$$

$$= \tfrac{1}{2}(0.0470\text{ kg})(52.0\text{ m/s})^2 + (0.0470\text{ kg})\left(9.80\text{ m/s}^2\right)(0\text{ m} - 24.6\text{ m}) = \boxed{52.2\text{ J}}$$

b. The conservation of mechanical energy, Equation 6.9b, states that

$$\underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{E_f} = \underbrace{\tfrac{1}{2}mv_0^2 + mgh_0}_{E_f}$$

The mass m can be eliminated algebraically from this equation, since it appears as a factor in every term. Solving for v_f and noting that the final height is $h_f = 24.6\text{ m} - 8.0\text{ m} = 16.6\text{ m}$ we have that

$$v_f = \sqrt{v_0^2 + 2g\left(h_0 - h_f\right)} = \sqrt{(52.0\text{ m/s})^2 + 2\left(9.80\text{ m/s}^2\right)(0\text{ m} - 16.6\text{ m})} = \boxed{48.8\text{ m/s}}$$

42. ***REASONING*** If air resistance is ignored, the only nonconservative force that acts on the person is the tension in the rope. However, since the tension always points perpendicular to the circular path of the motion, it does no work, and the principle of conservation of mechanical energy applies.

SOLUTION Let the initial position of the person be at the top of the cliff, a distance h_0 above the water. Then, applying the conservation principle to path 2, we have

$$\underbrace{\frac{1}{2}mv_f^2 + mgh_f}_{E_f\ \text{(at water)}} = \underbrace{\frac{1}{2}mv_0^2 + mgh_0}_{E_0\ \text{(at release point)}} \qquad (6.9b)$$

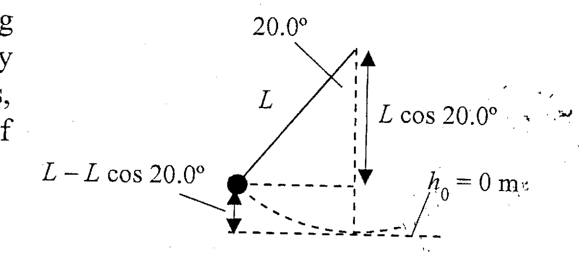
Solving this relation for the speed at the release point, we have

$$v_0 = \sqrt{v_f^2 + 2g\left(h_f - h_0\right)}$$

But $v_f = 13.0$ m/s, since the speed of entry is the same for either path. Therefore,

$$v_0 = \sqrt{v_f^2 + 2g\left(h_f - h_0\right)} = \sqrt{(13.0\text{ m/s})^2 + 2\left(9.80\text{ m/s}^2\right)(-5.20\text{ m})} = \boxed{8.2\text{ m/s}}$$

REASONING AND SOLUTION Since friction and air resistance are negligible, mechanical energy is conserved. Thus, the ball will have the same speed at the bottom of its swing whether it is moving toward or away from the crane. As the drawing shows, when the cable swings to an angle of 20.0°, the ball will rise a distance of



$$h = L\,(1 - \cos 20.0°)$$

where L is the length of the cable. Applying the conservation of energy with $h_0 = 0$ m gives

$$\tfrac{1}{2}mv_0^2 = \tfrac{1}{2}mv_f^2 + mgh$$

Solving for v_f gives

$$v_f = \sqrt{v_0^2 - 2gL(1 - \cos 20.0°)}$$

$$= \sqrt{(5.00\text{ m/s})^2 - 2\left(9.80\text{ m/s}^2\right)(12.0\text{ m})(1 - \cos 20.0°)} = \boxed{3.29\text{ m/s}}$$

44. ***REASONING*** To find the maximum height H above the end of the track we will analyze the projectile motion of the skateboarder after she leaves the track. For this analysis we will use the principle of conservation of mechanical energy, which applies because friction and air resistance are being ignored. In applying this principle to the projectile motion, however, we will need to know the speed of the skateboarder when she leaves the track. Therefore, we will begin by determining this speed, also using the conservation principle in the process. Our approach, then, uses the conservation principle twice.

SOLUTION Applying the conservation of mechanical energy in the form of Equation 6.9b, we have

$$\underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{\substack{\text{Final mechanical energy}\\ \text{at end of track}}} = \underbrace{\tfrac{1}{2}mv_0^2 + mgh_0}_{\substack{\text{Initial mechanical energy}\\ \text{on flat part of track}}}$$

We designate the flat portion of the track as having a height $h_0 = 0$ m and note from the drawing that its end is at a height of $h_f = 0.40$ m above the ground. Solving for the final speed at the end of the track gives

$$v_f = \sqrt{v_0^2 + 2g\left(h_0 - h_f\right)} = \sqrt{(5.4\text{ m/s})^2 + 2\left(9.80\text{ m/s}^2\right)\left[(0\text{ m}) - (0.40\text{ m})\right]} = 4.6\text{ m/s}$$

This speed now becomes the initial speed $v_0 = 4.6$ m/s for the next application of the conservation principle. At the maximum height of her trajectory she is traveling horizontally with a speed v_f that equals the horizontal component of her launch velocity. Thus, for the next application of the conservation principle $v_f = (4.6 \text{ m/s}) \cos 48°$. Applying the conservation of mechanical energy again, we have

$$\underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{\substack{\text{Final mechanical energy} \\ \text{at maximum height of trajectory}}} = \underbrace{\tfrac{1}{2}mv_0^2 + mgh_0}_{\substack{\text{Initial mechanical energy} \\ \text{upon leaving the track}}}$$

Recognizing that $h_0 = 0.40$ m and $h_f = 0.40$ m + H and solving for H give

$$\tfrac{1}{2}mv_f^2 + mg\left[(0.40 \text{ m}) + H\right] = \tfrac{1}{2}mv_0^2 + mg(0.40 \text{ m})$$

$$H = \frac{v_0^2 - v_f^2}{2g} = \frac{(4.6 \text{ m/s})^2 - \left[(4.6 \text{ m/s})\cos 48°\right]^2}{2(9.80 \text{ m/s}^2)} = \boxed{0.60 \text{ m}}$$

45. SSM ***REASONING*** Friction and air resistance are being ignored. The normal force from the slide is perpendicular to the motion, so it does no work. Thus, no net work is done by nonconservative forces, and the principle of conservation of mechanical energy applies.

SOLUTION Applying the principle of conservation of mechanical energy to the swimmer at the top and the bottom of the slide, we have

$$\underbrace{\frac{1}{2}mv_f^2 + mgh_f}_{E_f} = \underbrace{\frac{1}{2}mv_0^2 + mgh_0}_{E_0}$$

If we let h be the height of the bottom of the slide above the water, $h_f = h$, and $h_0 = H$. Since the swimmer starts from rest, $v_0 = 0$ m/s, and the above expression becomes

$$\frac{1}{2}v_f^2 + gh = gH$$

Solving for H, we obtain

$$H = h + \frac{v_f^2}{2g}$$

Before we can calculate H, we must find v_f and h. Since the velocity in the horizontal direction is constant,

$$v_f = \frac{\Delta x}{\Delta t} = \frac{5.00 \text{ m}}{0.500 \text{ s}} = 10.0 \text{ m/s}$$

The vertical displacement of the swimmer after leaving the slide is, from Equation 3.5b (with down being negative),

$$y = \tfrac{1}{2}a_y t^2 = \tfrac{1}{2}(-9.80 \text{ m/s}^2)(0.500 \text{ s})^2 = -1.23 \text{ m}$$

Therefore, $h = 1.23$ m. Using these values of v_f and h in the above expression for H, we find

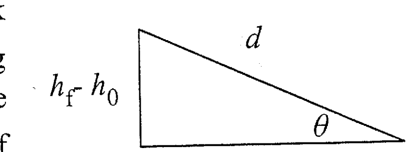
$$H = h + \frac{v_f^2}{2g} = 1.23 \text{ m} + \frac{(10.0 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)} = \boxed{6.33 \text{ m}}$$

46. ***REASONING*** We are neglecting air resistance and friction, which eliminates two nonconservative forces from consideration. Another nonconservative force acting on the semitrailer is the normal force exerted by the ramp. But this force does no work because it is perpendicular to the ramp and the semitrailer's velocity. Hence, the semi-trailer's total mechanical energy is conserved, and we will apply the energy conservation principle to determine the initial velocity v_0 of the truck.

SOLUTION The truck coasts to a stop, so we know that $v_f = 0$ m/s. Therefore, the energy conservation principle gives

$$\underbrace{\left(\tfrac{1}{2}mv_f^2 + mgh_f\right)}_{E_f} = \underbrace{\left(\tfrac{1}{2}mv_0^2 + mgh_0\right)}_{E_0} \quad \text{or} \quad \cancel{m}g\left(h_f - h_0\right) = \tfrac{1}{2}\cancel{m}v_0^2 \quad \text{or} \quad g\left(h_f - h_0\right) = \tfrac{1}{2}v_0^2 \quad (1)$$

Note that $h_f - h_0$ is the vertical height up which the truck climbs on the ramp, as the drawing indicates. The drawing also indicates that $h_f - h_0$ is related to the distance d the truck coasts along the ramp and the ramp's angle θ of inclination. The side $h_f - h_0$ is opposite the angle θ, and d is the hypotenuse, so we solve $\sin\theta = \dfrac{h_f - h_0}{d}$ (Equation 1.1) to find that $h_f - h_0 = d\sin\theta$.



Substituting $d\sin\theta$ for $h_f - h_0$ in Equation (1), we obtain

$$gd\sin\theta = \tfrac{1}{2}v_0^2 \quad \text{or} \quad v_0^2 = 2gd\sin\theta \quad \text{or} \quad v_0 = \sqrt{2gd\sin\theta}$$

When the semitrailer enters the ramp, therefore, its speed is

$$v_0 = \sqrt{2\left(9.80 \text{ m/s}^2\right)(154 \text{ m})\sin 14.0°} = \boxed{27.0 \text{ m/s}}$$

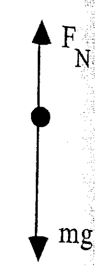
47. ***REASONING AND SOLUTION*** If air resistance is ignored, the only nonconservative force that acts on the skier is the normal force exerted on the skier by the snow. Since this force is always perpendicular to the direction of the displacement, the work done by the normal force is zero. We can conclude, therefore, that mechanical energy is conserved.

$$\frac{1}{2}mv_0^2 + mgh_0 = \frac{1}{2}mv_f^2 + mgh_f$$

Since the skier starts from rest $v_0 = 0$ m/s. Let h_f define the zero level for heights, then the final gravitational potential energy is zero. This gives

$$mgh_0 = \frac{1}{2}mv_f^2 \quad (1)$$

At the crest of the second hill, the two forces that act on the skier are the normal force and the weight of the skier. The resultant of these two forces provides the necessary centripetal force to keep the skier moving along the circular arc of the hill. When the skier *just loses contact* with the snow, the normal force is zero and the weight of the skier must provide the necessary centripetal force.



$$mg = \frac{mv_f^2}{r} \quad \text{so that} \quad v_f^2 = gr \quad (2)$$

Substituting this expression for v_f^2 into Equation (1) gives

$$mgh_0 = \frac{1}{2}mgr$$

Solving for h_0 gives

$$h_0 = \frac{r}{2} = \frac{36\text{ m}}{2} = \boxed{18\text{ m}}$$

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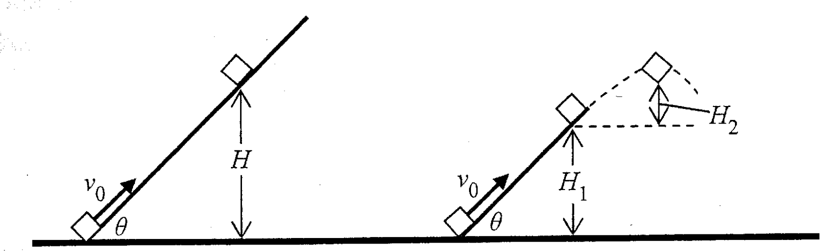
48. ***REASONING*** The principle of conservation of mechanical energy provides the solution to both parts of this problem. In applies in both cases because the tracks are frictionless (and we assume that air resistance is negligible).

When the block on the longer track reaches its maximum height, its final total mechanical energy consists only of gravitational potential energy, because it comes to a momentary halt at this point. Thus, its final speed is zero, and, as a result, its kinetic energy is also zero. In contrast, when the block on the shorter track reaches the top of its trajectory after leaving the track, its final total mechanical energy consists of part kinetic and part potential energy. At the top of the trajectory the block is still moving horizontally, with a velocity that equals the horizontal velocity component that it had when it left the track (assuming that air

resistance is negligible). Thus, at the top of the trajectory the block has some kinetic energy.

We can expect that the height H is greater than the height $H_1 + H_2$. To see why, note that both blocks have the same initial kinetic energy, since each has the same initial speed. Moreover, the total mechanical energy is conserved. Therefore, the initial kinetic energy is converted to potential energy as each block moves upward. On the longer track, the final total mechanical energy is all potential energy, whereas on the shorter track it is only part potential energy, as discussed previously. Since gravitational potential energy is proportional to height, the final height is greater for the block with the greater potential energy, or the one on the longer track.

SOLUTION The two inclines in the problem are as follows:



Longer track　　　Shorter track

a. **Longer track:** Applying the principle of conservation of mechanical energy for the longer track gives

$$\underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{\text{Final total mechanical energy}} = \underbrace{\tfrac{1}{2}mv_0^2 + mgh_0}_{\text{Initial total mechanical energy}}$$

Recognizing that $v_f = 0$ m/s, $h_f = H$, and $h_0 = 0$ m, we find that

$$\tfrac{1}{2}m(0\text{ m/s})^2 + mgH = \tfrac{1}{2}mv_0^2 + mg(0\text{ m})$$

$$H = \frac{v_0^2}{2g} = \frac{(7.00\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = \boxed{2.50\text{ m}}$$

b. **Shorter track:** We apply the conservation principle to the motion of the block after it leaves the track, in order to calculate the final height at the top of the trajectory, where $h_f = H_1 + H_2$ and the final speed is v_f. For the initial position at the end of the track we have $h_0 = H_1$ and an initial speed of v_{0T}. Thus, it follows that

$$\underbrace{\tfrac{1}{2}mv_f^2 + mg(H_1 + H_2)}_{\text{Final total mechanical energy}} = \underbrace{\tfrac{1}{2}mv_{0T}^2 + mgH_1}_{\text{Initial total mechanical energy}}$$

Solving for θ_f gives

$$\theta_f = \cos^{-1}\left(\frac{2}{3}\right) = \boxed{48°}$$

51. ***REASONING*** The work W_{nc} done by the nonconservative force exerted on the surfer by the wave is given by Equation 6.6, which states that this work is equal to the surfer's change in kinetic energy, $\frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2$, plus the change in her potential energy, $mgh_f - mgh_0$:

$$W_{nc} = \left(\tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_0^2\right) + \left(mgh_f - mgh_0\right) \tag{6.6}$$

All the terms in this equation are known, so we can evaluate the work.

SOLUTION We note that the difference between her final and initial heights is $h_f - h_0 = -2.7$ m, negative because her initial height h_0 is greater than her final height h_f. Thus, the work done by the nonconservative force is:

$$W_{nc} = \tfrac{1}{2}m\left(v_f^2 - v_0^2\right) + mg\left(h_f - h_0\right)$$

$$= \tfrac{1}{2}(59\text{ kg})\left[(9.5\text{ m/s})^2 - (1.4\text{ m/s})^2\right] + (59\text{ kg})(9.80\text{ m/s}^2)(-2.7\text{ m}) = \boxed{1.0\times10^3\text{ J}}$$

52. ***REASONING*** As the firefighter slides down the pole from a height h_0 to the ground ($h_f = 0$ m), his potential energy decreases to zero. At the same time, his kinetic energy increases as he speeds up from rest ($v_0 = 0$ m/s) to a final speed v_f. However, the upward nonconservative force of kinetic friction f_k, acting over a downward displacement h_0, does a negative amount of work on him: $W_{nc} = \left(f_k \cos 180°\right)h_0 = -f_k h_0$ (Equation 6.1). This work decreases his total mechanical energy E. Applying the work-energy theorem (Equation 6.8) with $h_f = 0$ m and $v_0 = 0$ m/s, we obtain

$$W_{nc} = \left(\tfrac{1}{2}mv_f^2 + mgh_f\right) - \left(\tfrac{1}{2}mv_0^2 + mgh_0\right) \tag{6.8}$$

$$\underbrace{-f_k h_0}_{W_{nc}} = \underbrace{\left(\tfrac{1}{2}mv_f^2 + 0\text{ J}\right)}_{E_f} - \underbrace{\left(0\text{ J} + mgh_0\right)}_{E_0} = \tfrac{1}{2}mv_f^2 - mgh_0 \tag{1}$$

SOLUTION Solving Equation (1) for the height h_0 gives

$$mgh_0 - f_k h_0 = \tfrac{1}{2}mv_f^2 \quad \text{or} \quad h_0\left(mg - f_k\right) = \tfrac{1}{2}mv_f^2 \quad \text{or} \quad h_0 = \frac{mv_f^2}{2\left(mg - f_k\right)}$$

The distance h_0 that the firefighter slides down the pole is, therefore,

$$h_0 = \frac{(93\text{ kg})(3.4\text{ m/s})^2}{2\left[(93\text{ kg})(9.80\text{ m/s}^2) - 810\text{ N}\right]} = \boxed{5.3\text{ m}}$$

53. $\boxed{\text{SSM}}$ ***REASONING AND SOLUTION*** The work-energy theorem can be used to determine the change in kinetic energy of the car according to Equation 6.8:

$$W_{nc} = \underbrace{\left(\tfrac{1}{2}mv_f^2 + mgh_f\right)}_{E_f} - \underbrace{\left(\tfrac{1}{2}mv_0^2 + mgh_0\right)}_{E_0}$$

The nonconservative forces are the forces of friction and the force due to the chain mechanism. Thus, we can rewrite Equation 6.8 as

$$W_{\text{friction}} + W_{\text{chain}} = \left(\text{KE}_f + mgh_f\right) - \left(\text{KE}_0 + mgh_0\right)$$

We will measure the heights from ground level. Solving for the change in kinetic energy of the car, we have

$$\text{KE}_f - \text{KE}_0 = W_{\text{friction}} + W_{\text{chain}} - mgh_f + mgh_0$$

$$= -2.00\times10^4\text{ J} + 3.00\times10^4\text{ J} - (375\text{ kg})(9.80\text{ m/s}^2)(20.0\text{ m})$$

$$+ (375\text{ kg})(9.80\text{ m/s}^2)(5.00\text{ m}) = \boxed{-4.51\times10^4\text{ J}}$$

54. ***REASONING*** We will use the work-energy theorem $W_{nc} = E_f - E_0$ (Equation 6.8) to find the speed of the student. W_{nc} is the work done by the kinetic frictional force and is negative because the force is directed opposite to the displacement of the student.

SOLUTION The work-energy theorem states that

$$W_{nc} = \underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{E_f} - \underbrace{\left(\tfrac{1}{2}mv_0^2 + mgh_0\right)}_{E_0} \tag{6.8}$$

Solving for $\overline{F}_R$ gives

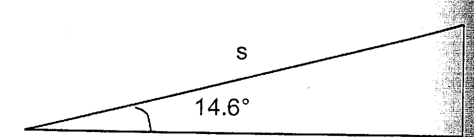
$$\overline{F}_R = \frac{\frac{1}{2}m\left(v_f^2 - v_0^2\right) + mg\left(h_f - h_0\right)}{-s}$$

$$= \frac{\frac{1}{2}(0.750\text{ kg})\left[(0\text{ m/s})^2 - (18.0\text{ m/s})^2\right] + (0.750\text{ kg})\left(9.80\text{ m/s}^2\right)(11.8\text{ m})}{-(11.8\text{ m})} = \boxed{2.9\text{ N}}$$

79. SSM ***REASONING AND SOLUTION*** We will assume that the tug-of-war rope remains parallel to the ground, so that the force that moves team B is in the same direction as the displacement. According to Equation 6.1, the work done by team A is

$$W = (F\cos\theta)s = (1100\text{ N})(\cos 0°)(2.0\text{ m}) = \boxed{2.2\times10^3\text{ J}}$$

80. ***REASONING AND SOLUTION***
The vertical height of the skier is $h = s \sin 14.6°$ so



$\Delta PE = mgs \sin 14.6°$

$= (75.0\text{ kg})(9.80\text{ m/s}^2)(2830\text{ m}) \sin 14.6°$

$= \boxed{5.24\times10^5\text{ J}}$

81. ***REASONING*** The net work done by the pushing force and the frictional force is zero, and our solution is focused on this fact. Thus, we express this net work as $W_P + W_f = 0$, where W_P is the work done by the pushing force and W_f is the work done by the frictional force. We will substitute for each individual work using Equation 6.1 [$W = (F\cos\theta)s$] and solve the resulting equation for the magnitude P of the pushing force.

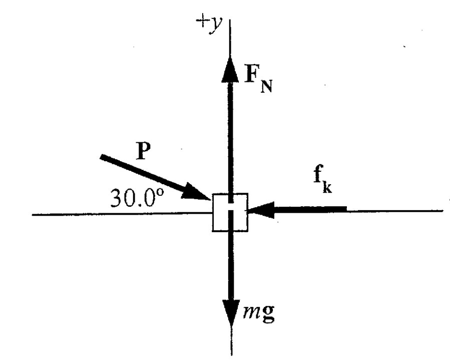
SOLUTION According to Equation 6.1, the work done by the pushing force is

$$W_P = (P\cos 30.0°)\,s = 0.866\,P\,s$$

The frictional force opposes the motion, so the angle between the force and the displacement is 180°. Thus, the work done by the frictional force is

$$W_f = (f_k \cos 180°)\,s = -f_k\,s$$

Equation 4.8 indicates that the magnitude of the kinetic frictional force is $f_k = \mu_k F_N$, where F_N is the magnitude of the normal force acting on the crate. The free-body diagram shows the forces acting on the crate. Since there is no acceleration in the vertical direction, the y component of the net force must be zero:



$$F_N - mg - P\sin 30.0° = 0$$

Therefore,

$$F_N = mg + P\sin 30.0°$$

It follows, then, that the magnitude of the frictional force is

$$f_k = \mu_k F_N = \mu_k (mg + P\sin 30.0°)$$

Suppressing the units, we find that the work done by the frictional force is

$$W_f = -f_k s = -(0.200)[(1.00\times10^2\text{ kg})(9.80\text{ m/s}^2) + 0.500P]s = -(0.100P + 196)s$$

Since the net work is zero, we have

$$W_P + W_f = 0.866\,Ps - (0.100P + 196)s = 0$$

Eliminating s algebraically and solving for P gives $\boxed{P = 256\text{ N}}$.

82. ***REASONING*** The average power generated by the tension in the cable is equal to the work done by the tension divided by the elapsed time (Equation 6.10a). The work can be related to the change in the lift's kinetic and potential energies via the work-energy theorem.

SOLUTION
a. The average power is

$$\overline{P} = \frac{W_{nc}}{t} \tag{6.10a}$$

where W_{nc} is the work done by the nonconservative tension force. This work is related to the lift's kinetic and potential energies by Equation 6.6, $W_{nc} = \left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2\right) + \left(mgh_f - mgh_0\right)$, so the average power is

$$\overline{P} = \frac{W_{nc}}{t} = \frac{\left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2\right) + \left(mgh_f - mgh_0\right)}{t}$$