Chapter 11, Conceptual Questions

11.5. The ball's kinetic energy is equal to the work done on it by gravity. Since work is force × distance, the kinetic energy of the ball increases by equal amounts in equal distance intervals.

11.7. The kinetic energies are equal. Equal forces are applied over equal displacements so that the same work is done on each. Thus, the change in kinetic energy is the same. Because $K_i = 0$, $\Delta K = K_f$. (The plastic will be moving 10 times faster, however.)

11.8. The work is the same in both cases, since the work done against gravity is $-m_g \Delta y$, and Δy, the change in height, is the same in both cases.

11.11. The kinetic energy was dissipated as thermal energy by friction between the tires and the road and in the brakes.

11.12. Gravitational potential energy is transformed into thermal energy. There is no change in the kinetic energy.

11.13. **(a)** Push a puck with force F across a frictionless level surface. With the puck as the system, $W_{ext} = F\Delta x = \Delta K$. The gravitational potential energy does not change because $\Delta y = 0$. Since the surface is frictionless, $\Delta E_{th} = 0$.
(b) Push a box across a rough level surface at constant speed. The system is the box. Again, $\Delta y = 0$, but now $\Delta K = 0$, and friction dissipates the external work done by the push as thermal energy.

11.14. Power is energy per time. The energy required to lift a beam a height Δy is the same as the change in gravitational potential energy of the beam. Power $P = \frac{W}{\Delta t} = \frac{mg\Delta y}{\Delta t}$. So doubling Δy and halving Δt requires a different power $P' = \frac{mg(2\Delta y)}{(\frac{1}{2}\Delta t)} = 4\frac{mg\Delta y}{\Delta t} = 4P$. The power must be increased by a factor of 4.

Chapter 11, Exercises and Problems

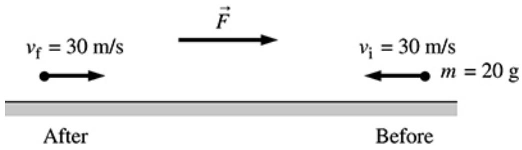
11.7. Solve: (a) $W = \vec{F}\cdot\Delta\vec{r} = (6.0\hat{i} - 3.0\hat{j})\cdot(2.0\hat{i})\ \text{N}\cdot\text{m} = (12.0\hat{i}\cdot\hat{i} - 3.0\hat{j}\cdot\hat{i})\ \text{J} = 12.0\ \text{J}.$

(b) $W = \vec{F}\cdot\Delta\vec{r} = (6.0\hat{i} - 3.0\hat{j})\cdot(2.0\hat{j})\ \text{N}\cdot\text{m} = (12.0\hat{i}\cdot\hat{j} - 6.0\hat{j}\cdot\hat{j})\ \text{J} = -6.0\ \text{J}.$

11.8. Solve: (a) $\vec{W} = \vec{F}\cdot\Delta\vec{r} = (-4.0\hat{i} - 6.0\hat{j})\ \text{N}\cdot(3.0\hat{i})\ \text{m} = (-12.0\hat{i}\cdot\hat{i} + 12.0\hat{j}\cdot\hat{i})\ \text{J} = -12.0\ \text{J}.$

(b) $\vec{W} = \vec{F}\cdot\Delta\vec{r} = (-4.0\hat{i} - 6.0\hat{j})\ \text{N}\cdot(-3.0\hat{i} + 2.0\hat{j})\ \text{m} = (12.0 - 12.0)\ \text{J} = 0\ \text{J}.$

11.9. Model: Use the work-kinetic energy theorem to find the net work done on the particle.
Visualize:

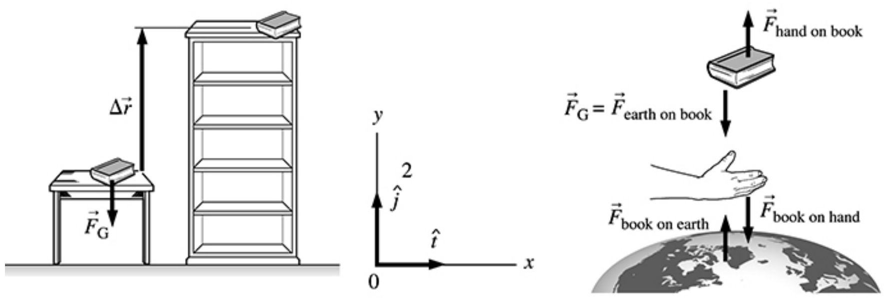


Solve: From the work-kinetic energy theorem,

$$W = \Delta K = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_0^2 = \frac{1}{2}m\left(v_1^2 - v_0^2\right) = \frac{1}{2}(0.020\ \text{kg})[(30\ \text{m/s})^2 - (-30\ \text{m/s})^2] = 0\ \text{J}$$

Assess: Negative work is done in slowing down the particle to rest, and an equal amount of positive work is done in bringing the particle to the original speed but in the opposite direction.

11.10. Model: Work done by a force $\vec{F}$ on a particle is defined as $\vec{W} = \vec{F}\cdot\Delta\vec{r}$, where $\Delta\vec{r}$ is the particle's displacement.
Visualize:



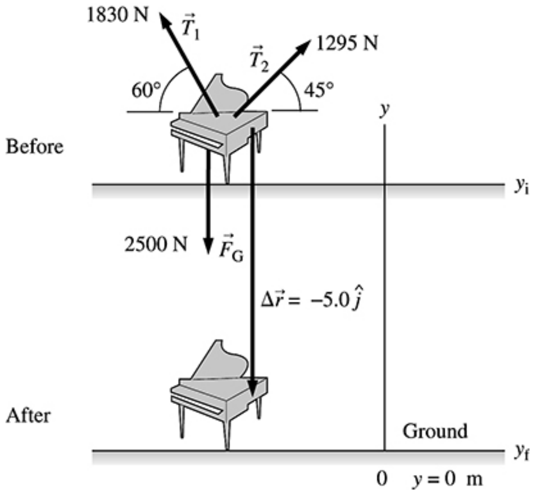
Solve: (a) The work done by gravity is

$$W_g = \vec{F}_G\cdot\Delta\vec{r} = (-mg\hat{j})\ \text{N}\cdot(2.25 - 0.75)\hat{j}\ \text{m} = -(2.0\ \text{kg})(9.8\ \text{m/s}^2)(1.50\ \text{m})\ \text{J} = -29\ \text{J}$$

(b) The work done by hand is $W_H = \vec{F}_{\text{hand on book}}\cdot\Delta\vec{r}$. As long as the book does not accelerate,

$$\vec{F}_{\text{hand on book}} = -\vec{F}_{\text{earth on book}} = -(-mg\hat{j}) = mg\hat{j}$$
$$\Rightarrow W_H = (mg\hat{j})\cdot(2.25 - 0.75)\hat{j}\ \text{m} = (2.0\ \text{kg})(9.8\ \text{m/s}^2)(1.50\ \text{m}) = 29\ \text{J}$$

11.11. Model: Model the piano as a particle and use $W = \vec{F} \cdot \Delta\vec{r}$, where W is the work done by the force $\vec{F}$ through the displacement $\Delta\vec{r}$.
Visualize:



Solve: For the force $\vec{F}_G$:

$$W = \vec{F} \cdot \Delta\vec{r} = \vec{F}_G \cdot \Delta\vec{r} = (F_g)(\Delta r)\cos 0° = (2500 \text{ N})(5.00 \text{ m})(1) = 1.250 \times 10^4 \text{ J}$$

For the tension $\vec{T}_1$:

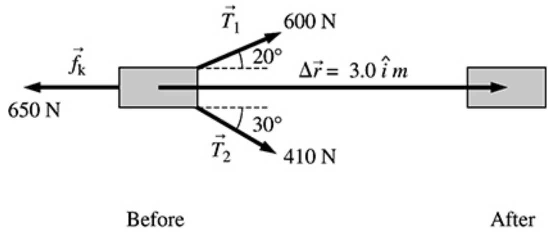
$$W = \vec{T}_1 \cdot \Delta\vec{r} = (T_1)(\Delta r)\cos(150°) = (1830 \text{ N})(5.00 \text{ m})(-0.8660) = -7.92 \times 10^3 \text{ J}$$

For the tension $\vec{T}_2$:

$$W = \vec{T}_2 \cdot \Delta\vec{r} = (T_2)(\Delta r)\cos(135°) = (1295 \text{ N})(5.00 \text{ m})(-0.7071) = -4.58 \times 10^3 \text{ J}$$

Assess: Note that the displacement $\Delta\vec{r}$ in all the above cases is directed downwards along $-\hat{j}$.

11.12. Model: Model the crate as a particle and use $W = \vec{F} \cdot \Delta\vec{r}$, where W is the work done by a force $\vec{F}$ on a particle and $\Delta\vec{r}$ is the particle's displacement.
Visualize:



Solve: For the force $\vec{f}_k$:

$$W = \vec{f}_k \cdot \Delta\vec{r} = f_k(\Delta r)\cos(180°) = (650 \text{ N})(3.0 \text{ m})(-1) = -1.95 \text{ kJ}$$

For the tension $\vec{T}_1$:

$$W = \vec{T}_1 \cdot \Delta\vec{r} = (T_1)(\Delta r)\cos 20° = (600 \text{ N})(3.0 \text{ m})(0.9397) = 1.69 \text{ kJ}$$

For the tension $\vec{T}_2$:

$$W = \vec{T}_2 \cdot \Delta\vec{r} = (T_2)(\Delta r)\cos 30° = (410 \text{ N})(3.0 \text{ m})(0.866) = 1.07 \text{ kJ}$$

Assess: Negative work done by the force of kinetic friction ($\vec{f}_k$) means that 1.95 kJ of energy has been transferred *out* of the crate.

11.13. Model: Model the 2.0 kg object as a particle, and use the work-kinetic energy theorem.
Visualize: Please refer to Figure EX11.13. For each of the five intervals the velocity-versus-time graph gives the initial and final velocities. The mass of the object is 2.0 kg.
Solve: According to the work-kinetic energy theorem:

$$W = \Delta K = \frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 = \frac{1}{2}m\left(v_f^2 - v_i^2\right)$$

Interval AB: $v_i = 2\text{ m/s}, \quad v_f = -2\text{ m/s} \Rightarrow W = \frac{1}{2}(2.0\text{ kg})[(-2\text{ m/s})^2 - (2\text{ m/s})^2] = 0\text{ J}$

Interval BC: $v_i = -2\text{ m/s}, \quad v_f = -2\text{ m/s} \Rightarrow W = \frac{1}{2}(2.0\text{ kg})[(-2\text{ m/s})^2 - (-2\text{ m/s})^2] = 0\text{ J}$

Interval CD: $v_i = -2\text{ m/s}, \quad v_f = 0\text{ m/s} \Rightarrow W = \frac{1}{2}(2.0\text{ kg})[(0\text{ m/s})^2 - (-2\text{ m/s})^2] = -4.0\text{ J}$

Interval DE: $v_i = 0\text{ m/s}, \quad v_f = 2\text{ m/s} \Rightarrow W = \frac{1}{2}(2.0\text{ kg})[(2\text{ m/s})^2 - (0\text{ m/s})^2] = +4.0\text{ J}$

Interval EF: $v_i = 2\text{ m/s}, \quad v_f = 1\text{ m/s} \Rightarrow W = \frac{1}{2}(2.0\text{ kg})[(1\text{ m/s})^2 - (2\text{ m/s})^2] = -3.0\text{ J}$

Assess: The work done is zero in intervals AB and BC. In the interval $\text{CD} + \text{DE}$ the total work done is zero. It is not whether v is positive or negative that counts because $K \propto v^2$. What is important is the magnitude of v and how v changes.

11.14. Model: Use the definition of work.
Visualize: Please refer to Figure EX11.14.
Solve: Work is defined as the area under the force-versus-position graph:

$$W = \int_{s_i}^{s_f} F_s\, ds = \text{area under the force curve}$$

Interval 0–1 m: $W = (4.0\text{ N})(1.0\text{ m} - 0.0\text{ m}) = 4.0\text{ J}$
Interval 1–2 m: $W = (4.0\text{ N})(0.5\text{ m}) + (-4.0\text{ N})(0.5\text{ m}) = 0\text{ J}$
Interval 2–3 m: $W = \frac{1}{2}(-4.0\text{ N})(1\text{ m}) = -2.0\text{ J}$

11.15. Model: Use the work-kinetic energy theorem to find velocities.
Visualize: Please refer to Figure EX11.15.
Solve: The work-kinetic energy theorem is

$$\Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = W = \int_{x_i}^{x_f} F_x\, dx = \text{ area under the force curve from } x_i \text{ to } x_f$$

$$\Rightarrow \frac{1}{2}mv_f^2 - \frac{1}{2}(0.500\text{ kg})(2.0\text{m/s})^2 = \frac{1}{2}mv_f^2 - 1.0\text{ J} = \int_{0\text{ m}}^{x_f} F_x\, dx = \text{area from 0 to } x$$

At x=1 m: $\frac{1}{2}(0.500\text{ kg})v_f^2 - 1.0\text{ J} = 12.5\text{ J} \Rightarrow v_f = 7.35\text{ m/s}$

At $x = 2$ m: $\frac{1}{2}(0.500\text{ kg})v_f^2 - 1.0\text{ J} = 20\text{ J} \Rightarrow v_f = 9.17\text{ m/s}$

At $x = 3$ m: $\frac{1}{2}(0.500\text{ kg})v_f^2 - 1.0\text{ J} = 22.5\text{ J} \Rightarrow v_f = 9.70\text{ m/s}$

11.16. Model: Use the work-kinetic energy theorem.
Visualize: Please refer to Figure EX11.16.
Solve: The work-kinetc energy theorem is

$$\Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = W = \int_{x_i}^{x_f} F_x dx = \text{area under the force curve from } x_i \text{ to } x_f$$

$$\Rightarrow \frac{1}{2}mv_f^2 - \frac{1}{2}(2.0\text{ kg})(4.0\text{ m/s})^2 = \frac{1}{2}mv_f^2 - 16.0\text{ J} = \int_{0\text{ m}}^{x_f} F_x\, dx = \text{area from 0 to } x$$

At $x = 2$ m: $\frac{1}{2}(2.0\text{ kg})v_f^2 - 16.0\text{ J} = \frac{1}{2}(10\text{ N})(2\text{ m}) = 10\text{ J} \Rightarrow v_f = 5.1\text{ m/s}$

At $x = 4$ m: $\frac{1}{2}(2.0\text{ kg})v_f^2 - 16.0\text{ J} = 0\text{ J} \Rightarrow v_f = 4.0\text{ m/s}$

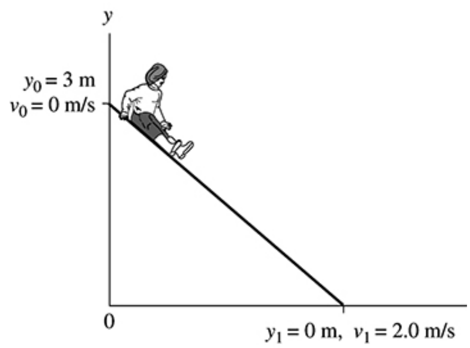
11.17. Model: Use the work-kinetic energy theorem.
Visualize: Please refer to Figure EX11.17.
Solve: The work-kinetic energy theorem is

$$\Delta K = W = \int_{x_i}^{x_f} F_x \, dx = \text{area of the } F_x\text{-versus-}x \text{ graph between } x_i \text{ and } x_f$$

$$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}(F_{max})(2 \text{ m})$$

Using $m = 0.500$ kg, $v_f = 6.0$ m/s, and $v_i = 2.0$ m/s, the above equation yields $F_{max} = 8.0$ N.
Assess: Problems in which the force is not a constant can not be solved using constant-acceleration kinematic equations.

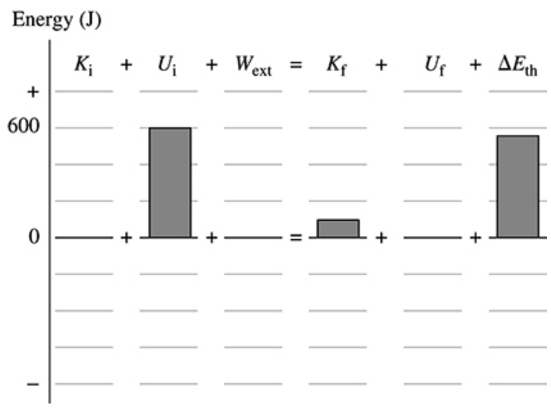
11.25. Visualize:



Solve: **(a)** $K_i = K_0 = \frac{1}{2}mv_0^2 = 0 \text{ J} \quad U_i = U_{g0} = mgy_0 = (20 \text{ kg})(9.8 \text{ m/s}^2)(3.0 \text{ m}) = 5.9\times10^2 \text{ J}$

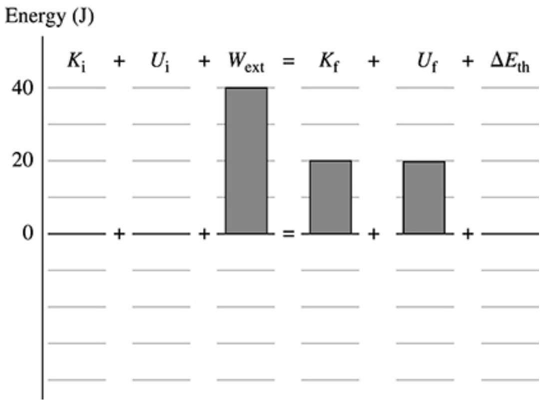
$$W_{ext} = 0 \text{ J} \quad K_f = K_1 = \frac{1}{2}mv_1^2 = \frac{1}{2}(20 \text{ kg})(2.0 \text{ m/s})^2 = 40 \text{ J} \quad U_f = U_{g1} = mgy_1 = 0 \text{ J}$$

At the top of the slide, the child has gravitational potential energy of 5.9×10^2 J. This energy is transformed into thermal energy of the child's pants and the slide and the kinetic energy of the child. This energy transfer and transformation is shown on the energy bar chart.
(b)



The change in the thermal energy of the slide and of the child's pants is $5.9\times10^2 \text{ J} - 40 \text{ J} = 5.5\times10^2 \text{ J}$.

11.29. Visualize: The tension of 20.0 N in the cable is an external force that does work on the block $W_{ext} =$ $(20.0 \text{ N})(2.00 \text{ m}) = 40.0 \text{ J}$, increasing the gravitational potential energy of the block. We placed the origin of our coordinate system on the initial resting position of the block, so we have $U_i = 0$ J and $U_f = mgy_f =$ $(1.02 \text{ kg})(9.8 \text{ m/s}^2)(2.00 \text{ m}) =$ 20.0 J. Also, $K_i = 0$ J, and $\Delta E_{th} = 0$ J. The energy bar chart shows the energy transfers and transformations.



Solve: The conservation of energy equation is

$$K_i + U_i + W_{ext} = K_f + U_f + \Delta E_{th} \Rightarrow 0\text{ J} + 0\text{ J} + 40.0\text{ J} = \frac{1}{2}mv_f^2 + 20.0\text{ J} + 0\text{ J}$$

$$\Rightarrow v_f = \sqrt{(20.0\text{ J})(2)/1.02\text{ kg}} = 6.26\text{ m/s}$$

11.30. **Model:** Model the elevator as a particle, and apply the conservation of energy equation.
Solve: The tension in the cable does work on the elevator to lift it. Because the cable is pulled by the motor, we say that the motor does the work of lifting the elevator.
(a) The energy conservation equation is $K_i + U_i + W_{ext} = K_f + U_f + \Delta E_{th}$. Using $K_i = 0\text{ J}, K_f = 0\text{ J},$ and $\Delta E_{th} = 0\text{ J}$ gives

$$W_{ext} = (U_f - U_i) = mg(y_f - y_i) = (1000\text{ kg})(9.8\text{ m/s}^2)(100\text{ m}) = 9.80\times10^5\text{ J}$$

(b) The power required to give the elevator this much energy in a time of 50 s is

$$P = \frac{W_{ext}}{\Delta t} = \frac{9.8\times10^5\text{ J}}{50\text{ s}} = 1.96\times10^4\text{ W}$$

Assess: Since 1 horsepower (hp) is 746 W, the power of the motor is 26 hp. This is a reasonable amount of power to lift a mass of 1000 kg to a height of 100 m in 50 s.

11.32. **Solve:** The power of the solar collector is the solar energy collected divided by time. The intensity of the solar energy striking the earth is the power divided by area. We have

$$P = \frac{\Delta E}{\Delta t} = \frac{150\times10^6\text{ J}}{3600\text{ s}} = 41{,}667\text{ W} \quad \text{and} \quad \text{intensity} = 1000\frac{\text{W}}{\text{m}^2}$$

$$\Rightarrow \text{Area of solar collector} = \frac{41{,}667\text{ W}}{1000\text{ W/m}^2} = 41.7\text{ m}^2$$

11.33. **Solve:** The night light consumes more energy than the hair dryer. The calculations are

$$1.2\text{ kW}\times10\text{ min} = 1.2\times10^3\times10\times60\text{ J} = 7.2\times10^5\text{ J}$$

$$10\text{ W}\times24\text{ hours} = 10\times24\times60\times60\text{ J} = 8.64\times10^5\text{ J}$$

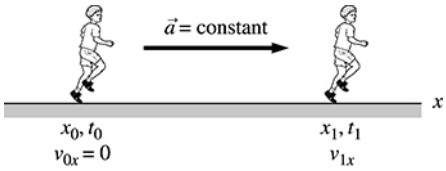
11.34. **Solve:** **(a)** A kilowatt hour is a kilowatt multiplied by 3600 seconds. It has the dimensions of energy.
(b) One kilowatt hour is energy

$$1\text{ kwh} = (1000\text{ J/s})(3600\text{ s}) = 3.6\times10^6\text{ J}$$

Thus

$$500\text{ kwh} = (500\text{ kwh})\left(\frac{3.6\times10^6\text{ J}}{1\text{ kwh}}\right) = 1.8\times10^9\text{ J}$$

11.35. **Model:** Model the sprinter as a particle, and use the constant-acceleration kinematic equations and the definition of power in terms of velocity.
Visualize:



Solve: **(a)** We can find the acceleration from the kinematic equations and the horizontal force from Newton's second law. We have

$$x = x_0 + v_{0x}(t_1 - t_0) + \frac{1}{2}a_x(t_1 - t_0)^2 \Rightarrow 50 \text{ m} = 0 \text{ m} + 0 \text{ m} + \frac{1}{2}a_x(7.0 \text{ s} - 0 \text{ s})^2 \Rightarrow a_x = 2.04 \text{ m/s}^2$$

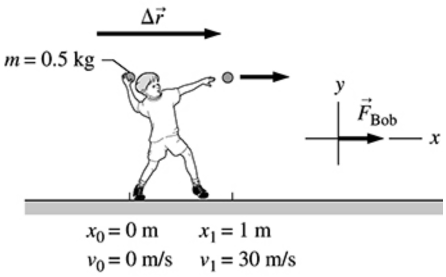
$$\Rightarrow F_x = ma_x = (50 \text{ kg})(2.04 \text{ m/s}^2) = 102 \text{ N}$$

(b) We obtain the sprinter's power output by using $P = \vec{F} \cdot \vec{v}$, where $\vec{v}$ is the sprinter's velocity. At $t = 2.0$ s the power is

$$P = (F_x)[v_{0x} + a_x(t - t_0)] = (102 \text{ N})[0 \text{ m/s} + (2.04 \text{ m/s}^2)(2.0 \text{ s} - 0 \text{ s})] = 0.42 \text{ kW}$$

The power at $t = 4.0$ s is 0.83 kW, and at $t = 6.0$ s the power is 1.25 kW.

11.42. **Model:** Model the rock as a particle, and apply the work-kinetic energy theorem.
Visualize:

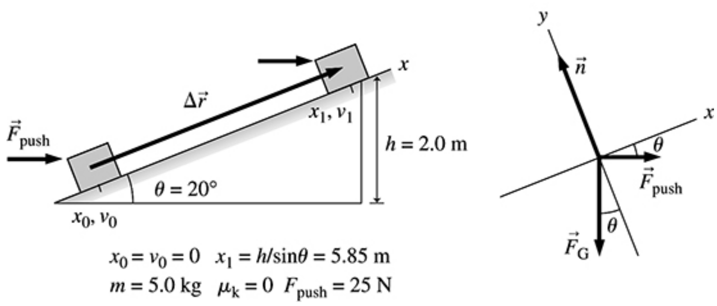


Solve: **(a)** The work done by Bob on the rock is

$$W_{Bob} = \Delta K = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_0^2 = \frac{1}{2}mv_1^2 = \frac{1}{2}(0.500 \text{ kg})(30 \text{ m/s})^2 = 225 \text{ J} = 2.3\times10^2 \text{ J}$$

(b) For a constant force, $W_{Bob} = F_{Bob}\Delta x \Rightarrow F_{Bob} = W_{Bob}/\Delta x = 2.3\times10^2$ N.
(c) Bob's power output is $P_{Bob} = F_{Bob}v_{rock}$ and will be a maximum when the rock has maximum speed. This is just as he releases the rock with $v_{rock} = v_1 = 30$ m/s. Thus, $P_{max} = F_{Bob}v_1 = (225 \text{ J})(30 \text{ m/s}) = 6750 \text{ W} = 6.8 \text{ kW}$.

11.43. **Model:** Model the crate as a particle, and use the work-kinetic energy theorem.
Visualize:



Solve: **(a)** The work-kinetic energy theorem is $\Delta K = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_0^2 = \frac{1}{2}mv_1^2 = W_{total}$. Three forces act on the box, so $W_{total} = W_{grav} + W_n + W_{push}$. The normal force is perpendicular to the motion, so $W_n = 0$ J. The other two forces do the following amount of work:

$$W_{push} = \vec{F}_{push} \cdot \Delta\vec{r} = F_{push}\Delta x \cos 20° = 137.4 \text{ J} \qquad W_{grav} = \vec{F}_G \cdot \Delta\vec{r} = (F_G)_x \Delta x = (-mg\sin 20°)\Delta x = -98.0 \text{ J}$$

Thus, $W_{total} = 39.4$ J, leading to a speed at the top of the ramp equal to

$$v_1 = \sqrt{\frac{2W_{\text{total}}}{m}} = \sqrt{\frac{2(39.4\text{ J})}{5.0\text{ kg}}} = 4.0\text{ m/s}$$

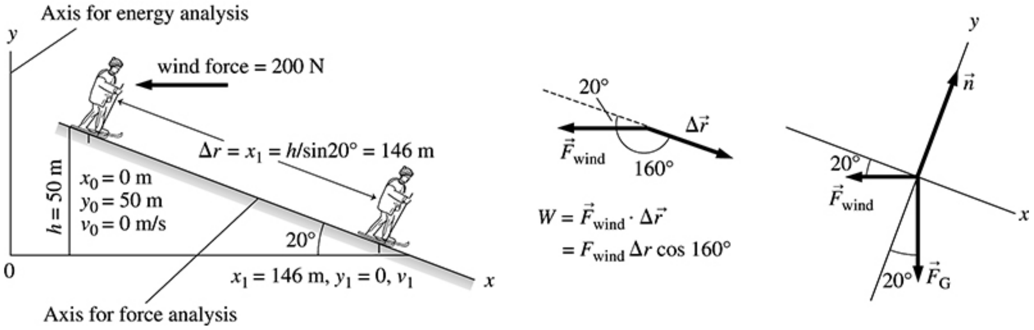
(b) The *x*-component of Newton's second law is

$$a_x = a = \frac{(F_{\text{net}})_x}{m} = \frac{F_{\text{push}}\cos 20° - F_{\text{G}}\sin 20°}{m} = \frac{F_{\text{push}}\cos 20° - mg\sin 20°}{m} = 1.35\text{ m/s}^2$$

Constant-acceleration kinematics with $x_1 = h/\sin 20° = 5.85\text{ m}$ gives the final speed

$$v_1^2 = v_0^2 + 2a(x_1 - x_0) = 2ax_1 \Rightarrow v_1 = \sqrt{2ax_1} = \sqrt{2(1.35\text{ m/s}^2)(5.85\text{ m})} = 4.0\text{ m/s}$$

11.44. Model: Model Sam strapped with skis as a particle, and apply the law of conservation of energy.
Visualize:



Solve: (a) The conservation of energy equation is

$$K_1 + U_{g1} + \Delta E_{\text{th}} = K_0 + U_{g0} + W_{\text{ext}}$$

The snow is frictionless, so $\Delta E_{\text{th}} = 0$ J. However, the wind is an external force doing work on Sam as he moves down the hill. Thus,

$$W_{\text{ext}} = W_{\text{wind}} = (K_1 + U_{g1}) - (K_0 + U_{g0})$$
$$= \left(\frac{1}{2}mv_1^2 + mgy_1\right) - \left(\frac{1}{2}mv_0^2 + mgy_0\right) = \left(\frac{1}{2}mv_1^2 + 0\text{ J}\right) - (0\text{ J} + mgy_0) = \frac{1}{2}mv_1^2 - mgy_0$$
$$\Rightarrow v_1 = \sqrt{2gy_0 + \frac{2W_{\text{wind}}}{m}}$$

We compute the work done by the wind as follows:

$$W_{\text{wind}} = \vec{F}_{\text{wind}} \cdot \Delta\vec{r} = F_{\text{wind}}\Delta r\cos 160° = (200\text{ N})(146\text{ m})\cos 160° = -27{,}400\text{ J}$$

where we have used $\Delta r = h/\sin 20° = 146$ m. Now we can compute

$$v_1 = \sqrt{2(9.8\text{ m/s}^2)(50\text{ m}) + \frac{2(-27{,}400\text{ J})}{75\text{ kg}}} = 15.7\text{ m/s}$$

(b) We will use a tilted coordinate system, with the *x*-axis parallel to the slope. Newton's second law for Sam is

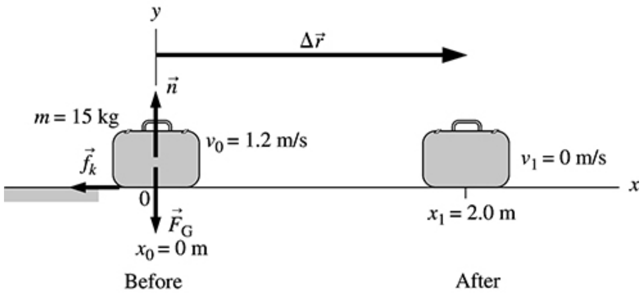
$$a_x = a = \frac{(F_{\text{net}})_x}{m} = \frac{F_{\text{G}}\sin 20° - F_{\text{wind}}\cos 20°}{m} = \frac{mg\sin 20° - F_{\text{wind}}\cos 20°}{m}$$
$$= \frac{(75\text{ kg})(9.8\text{ m/s}^2)\sin 20° - (200\text{ N})\cos 20°}{75\text{ kg}} = 0.846\text{ m/s}^2$$

Now we can use constant-acceleration kinematics as follows:

$$v_1^2 = v_0^2 + 2a(x_1 - x_0) = 2ax_1 \Rightarrow v_1 = \sqrt{2ax_1} = \sqrt{2(0.846\text{ m/s}^2)(146\text{ m})} = 15.7\text{ m/s}$$

Assess: We used a vertical *y*-axis for energy analysis, rather than a tilted coordinate system, because U_{g} is determined by its vertical position.

11.47. Model: Model the suitcase as a particle, use the model of kinetic friction, and use the work-kinetic energy theorem.
Visualize:



The net force on the suitcase is $\vec{F}_{net} = \vec{f}_k$.

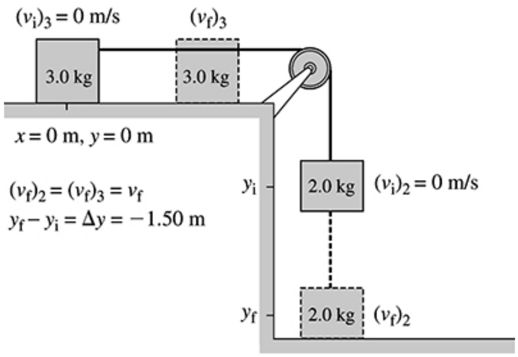
Solve: The work-kinetic energy theorem is

$$W_{net} = \Delta K = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_0^2 \Rightarrow \vec{F}_{net}\cdot\Delta\vec{r} = \vec{f}_k\cdot\Delta\vec{r} = 0\text{ J} - \frac{1}{2}mv_0^2 \Rightarrow (f_k)(x_1 - x_0)\cos180° = -\frac{1}{2}mv_0^2$$

$$\Rightarrow -\mu_k mg(x_1 - x_0) = -\frac{1}{2}mv_0^2 \Rightarrow \mu_k = \frac{v_0^2}{2g(x_1 - x_0)} = \frac{(1.2\text{ m/s})^2}{2(9.8\text{ m/s}^2)(2.0\text{ m } - 0\text{ m})} = 0.037$$

Assess: Friction transforms kinetic energy of the suitcase into thermal energy. In response, the suitcase slows down and comes to rest.

11.50. Model: Model the two blocks as particles. The two blocks make our system.
Visualize:



We place the origin of our coordinate system at the location of the 3.0 kg block.

Solve: **(a)** The conservation of energy equation is $K_f + U_{gf} + \Delta E_{th} = K_i + U_{gi} + W_{ext}$. Using $\Delta E_{th} = 0$ J and $W_{ext} = 0$ J we get

$$\frac{1}{2}m_2(v_f)_2^2 + \frac{1}{2}m_3(v_f)_3^2 + m_2g(y_f) = \frac{1}{2}m_2(v_i)_2^2 + \frac{1}{2}m_3(v_i)_3^2 + m_2g(y_i)$$

Noting that $(v_f)_2 = (v_f)_3 = v_f$ and $(v_i)_2 = (v_i)_3 = 0$ m/s, this becomes

$$\frac{1}{2}(m_2 + m_3)v_f^2 = -m_2g(y_f - y_i)$$

$$v_f = \sqrt{\frac{2m_2g(y_i - y_f)}{m_2 + m_3}} = \sqrt{\frac{2(2.0\text{ kg})(9.8\text{ m/s}^2)(1.50\text{ m})}{(2.0\text{ kg } + 3.0\text{ kg})}} = 3.4\text{ m/s}$$

(b) We will use the same energy conservation equation. However, this time

$$\Delta E_{th} = \mu_k(m_3g)(\Delta x) = (0.15)(3.0\text{ kg})(9.8\text{ m/s}^2)(1.50\text{ m}) = 6.615\text{ J}$$

The energy conservation equation is now

$$\frac{1}{2}m_2v_f^2 + \frac{1}{2}m_3v_f^2 + m_2gy_f + 6.615\text{ J } = \frac{1}{2}m_2(v_i)_2^2 + \frac{1}{2}m_3(v_1)_3^2 + m_2gy_i + 0\text{ J}$$

$$\frac{1}{2}(m_2+m_3)v_f^2 + 6.615\text{ J} = m_2 g(y_i - y_f) \Rightarrow v_f = \sqrt{\left(\frac{2}{m_2+m_3}\right)[m_2 g(y_i - y_f) - 6.615\text{ J}]}$$

$$= \sqrt{\left(\frac{2}{5.0\text{ kg}}\right)[(2.0\text{ kg})(9.8\text{ m/s}^2)(1.50\text{ m}) - 6.615\text{ J}]} = 3.0\text{ m/s}$$

Assess: A reduced speed when friction is present compared to when there is no friction is reasonable.

11.64. Solve: (a) The change in the potential energy of 1.0 kg of water in falling 25 m is $\Delta U_g = -mgh = -(1.0\text{ kg})(9.8\text{ m/s}^2)(25\text{ m}) = -245\text{ J} \approx -0.25\text{ kJ}$

(b) The power required of the dam is

$$P = \frac{W}{t} = \frac{W}{1\text{ s}} = 50\times10^6\text{ Watts} \Rightarrow W = 50\times10^6\text{ J}$$

That is, 50×10^6 J of energy is required per second for the dam. Out of the 245 J of lost potential energy, $(245\text{ J})(0.80) = 196\text{ J}$ is converted to electrical energy. Thus, the amount of water needed per second is $(50\times10^6\text{ J})(1\text{ kg}/196\text{ J}) = 255{,}000\text{ kg} \approx 2.6\times10^5\text{ kg}$.

11.65. Solve: The force required to tow a water skier at a speed v is $F_{tow} = Av$. Since power $P = Fv$, the power required to tow the water skier is $P_{tow} = F_{tow}v = Av^2$. We can find the constant A by noting that a speed of $v = 2.5$ mph requires a power of 2 hp. Thus,

$$(2\text{ hp}) = A(2.5\text{ mph})^2 \Rightarrow A = 0.32\frac{\text{hp}}{(\text{mph})^2}$$

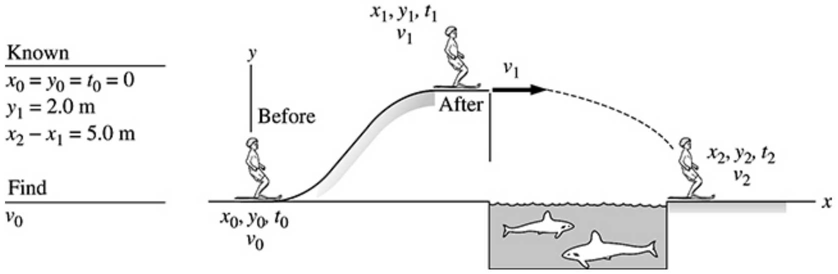
Now, the power required to tow a water skier at 7.5 mph is

$$P_{tow} = Av^2 = 0.32\frac{\text{hp}}{(\text{mph})^2}\cdot(7.5\text{ mph})^2 = 18\text{ hp}$$

Assess: Since $P \propto v^2$, a three-fold increase in velocity leads to a nine-fold increase in power.

11.73. Model: Model the water skier as a particle, apply the law of conservation of mechanical energy, and use the constant-acceleration kinematic equations.

Visualize:



We placed the origin of the coordinate system at the base of the frictionless ramp.

Solve: We'll start by finding the smallest speed v_1 at the top of the ramp that allows her to clear the shark tank. From the vertical motion for jumping the shark tank,

$$y_2 = y_1 + v_{1y}(t_2 - t_1) + \frac{1}{2}a_y(t_2 - t_1)^2$$

$$\Rightarrow 0\text{ m} = (2.0\text{ m}) + 0\text{ m} + \frac{1}{2}(-9.8\text{ m/s}^2)(t_2 - t_1)^2 \Rightarrow (t_2 - t_1) = 0.639\text{ s}$$

From the horizontal motion,

$$x_2 = x_1 + v_{1x}(t_2 - t_1) + \frac{1}{2}a_x(t_2 - t_1)^2$$

$$\Rightarrow (x_1 + 5.0\text{ m}) = x_1 + v_1(0.639\text{ s}) + 0\text{ m} \Rightarrow v_1 = \frac{5.0\text{ m}}{0.639\text{ s}} = 7.825\text{ m/s}$$

Having found the v_1 that will take the skier to the other side of the tank, we now use the energy equation to find the minimum speed v_0. We have

$$K_1 + U_{g1} = K_0 + U_{g0} \Rightarrow \frac{1}{2}mv_1^2 + mgy_1 = \frac{1}{2}mv_0^2 + mgy_0$$

$$v_0 = \sqrt{v_1^2 + 2g(y_1 - y_0)} = \sqrt{(7.825 \text{ m/s})^2 + 2(9.8 \text{ m/s}^2)(2.0 \text{ m})} = 10.0 \text{ m/s}$$