Chapter 8 Solutions

*P8.1 (a) The toaster coils take in energy by electrical transmission. They increase in internal energy and put out energy by heat into the air and energy by electromagnetic radiation as they start to glow. $\boxed{\bullet E_{int} = Q + T_{ET} + T_{ER}}$

(b) The car takes in energy by mass transfer. Its fund of chemical potential energy increases. As it moves, its kinetic energy increases and it puts out work on the air, energy by heat in the exhaust,
and a tiny bit of energy by mechanical waves in sound. $\boxed{\bullet K + \bullet U + \bullet E_{int} = W + Q + T_{MW} + T_{MT}}$

(c) You take in energy by mass transfer. Your fund of chemical potential energy increases. You are
always putting out energy by heat into the surrounding air. $\boxed{\bullet U = Q + T_{MT}}$

(d) Your house is in steady state, keeping constant energy as it takes in energy by electrical transmission to run the clocks and, we assume, an air conditioner. It absorbs sunlight, taking in energy by electromagnetic radiation. The exterior plenum of the air conditioner takes in cooler air and puts it out as warmer air, transferring out energy by mass transfer.
$\boxed{0 = Q + T_{MT} + T_{ET} + T_{ER}}$

P8.3 $U_i + K_i = U_f + K_f$: $\quad mgh + 0 = mg(2R) + \frac{1}{2}mv^2$

$$g(3.50R) = 2g(R) + \frac{1}{2}v^2$$

$$\boxed{v = \sqrt{3.00gR}}$$

$\sum F = m\frac{v^2}{R}$: $\quad n + mg = m\frac{v^2}{R}$

$$n = m\left[\frac{v^2}{R} - g\right] = m\left[\frac{3.00gR}{R} - g\right] = 2.00mg$$

$$n = 2.00\left(5.00\times10^{-3}\ \text{kg}\right)\left(9.80\ \text{m/s}^2\right)$$

$$= \boxed{0.0980\ \text{N downward}}$$

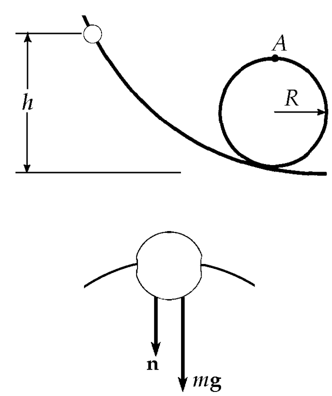

FIG. P8.3

P8.5 From conservation of energy for the block-spring-Earth system,

$$U_{gt} = U_{si}$$

or

$$(0.250 \text{ kg})(9.80 \text{ m/s}^2)h = \left(\frac{1}{2}\right)(5\,000 \text{ N/m})(0.100 \text{ m})^2$$

This gives a maximum height $h = \boxed{10.2 \text{ m}}$.

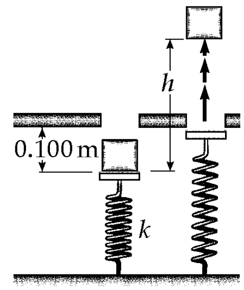

FIG. P8.5

P8.7 Using conservation of energy for the system of the Earth and the two objects

(a) $$(5.00 \text{ kg})g(4.00 \text{ m}) = (3.00 \text{ kg})g(4.00 \text{ m}) + \frac{1}{2}(5.00 + 3.00)v^2$$

$$v = \sqrt{19.6} = \boxed{4.43 \text{ m/s}}$$

(b) Now we apply conservation of energy for the system of the 3.00 kg object and the Earth during the time interval between the instant when the string goes slack and the instant at which the 3.00 kg object reaches its highest position in its free fall.

$$\frac{1}{2}(3.00)v^2 = mg\,\Delta y = 3.00g\Delta y$$

$$\Delta y = 1.00 \text{ m}$$

$$y_{max} = 4.00 \text{ m} + \Delta y = \boxed{5.00 \text{ m}}$$

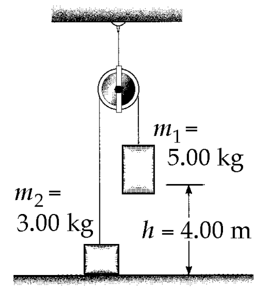

FIG. P8.7

P8.9 The force of tension and subsequent force of compression in the rod do no work on the ball, since they are perpendicular to each step of displacement. Consider energy conservation of the ball-Earth system between the instant just after you strike the ball and the instant when it reaches the top. The speed at the top is zero if you hit it just hard enough to get it there.

$K_i + U_{gi} = K_f + U_{gf}$:

$$\frac{1}{2}mv_i^2 + 0 = 0 + mg(2L)$$

$$v_i = \sqrt{4gL} = \sqrt{4(9.80)(0.770)}$$

$$v_i = \boxed{5.49 \text{ m/s}}$$

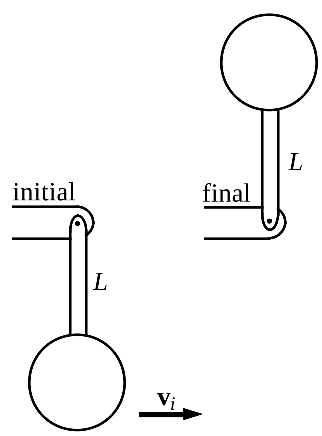

FIG. P8.9

P8.12 When block B moves up by 1 cm, block A moves down by 2 cm and the separation becomes 3 cm. We then choose the final point to be when B has moved up by $\frac{h}{3}$ and has speed $\frac{v_A}{2}$. Then A has moved down $\frac{2h}{3}$ and has speed v_A:

$$\left(K_A + K_B + U_g\right)_i = \left(K_A + K_B + U_g\right)_f$$

$$0 + 0 + 0 = \frac{1}{2}mv_A^2 + \frac{1}{2}m\left(\frac{v_A}{2}\right)^2 + \frac{mgh}{3} - \frac{mg2h}{3}$$

$$\frac{mgh}{3} = \frac{5}{8}mv_A^2$$

$$\boxed{v_A = \sqrt{\frac{8gh}{15}}}$$

P8.13 $\sum F_y = ma_y$: $n - 392\text{ N} = 0$

$n = 392\text{ N}$

$f_k = \mu_k n = (0.300)(392\text{ N}) = 118\text{ N}$

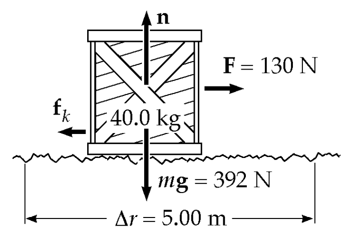

FIG. P8.13

(a) $W_F = F\Delta r\cos\theta = (130)(5.00)\cos 0° = \boxed{650\text{ J}}$

(b) $\Delta E_{int} = f_k\Delta x = (118)(5.00) = \boxed{588\text{ J}}$

(c) $W_n = n\Delta r\cos\theta = (392)(5.00)\cos 90° = \boxed{0}$

(d) $W_g = mg\Delta r\cos\theta = (392)(5.00)\cos(-90°) = \boxed{0}$

(e) $\Delta K = K_f - K_i = \sum W_{other} - \Delta E_{int}$

$$\frac{1}{2}mv_f^2 - 0 = 650\text{ J} - 588\text{ J} + 0 + 0 = \boxed{62.0\text{ J}}$$

(f) $v_f = \sqrt{\frac{2K_f}{m}} = \sqrt{\frac{2(62.0\text{ J})}{40.0\text{ kg}}} = \boxed{1.76\text{ m/s}}$

P8.15 (a) $W_g = mg\ell\cos(90.0° + \theta)$

$W_g = (10.0\text{ kg})(9.80\text{ m/s}^2)(5.00\text{ m})\cos 110° = \boxed{-168\text{ J}}$

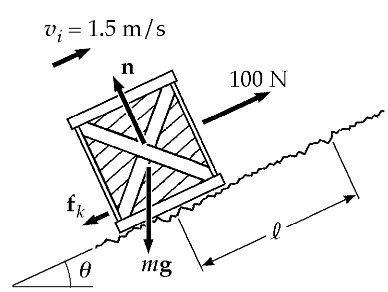

FIG. P8.15

(b) $f_k = \mu_k n = \mu_k mg\cos\theta$

$\Delta E_{int} = \ell f_k = \ell\mu_k mg\cos\theta$

$\Delta E_{int} = (5.00\text{ m})(0.400)(10.0)(9.80)\cos 20.0° = \boxed{184\text{ J}}$

(c) $W_F = F\ell = (100)(5.00) = \boxed{500\text{ J}}$

(d) $\Delta K = \sum W_{other} - \Delta E_{int} = W_F + W_g - \Delta E_{int} = \boxed{148\text{ J}}$

(e) $\Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$$v_f = \sqrt{\frac{2(\Delta K)}{m} + v_i^2} = \sqrt{\frac{2(148)}{10.0} + (1.50)^2} = \boxed{5.65 \text{ m/s}}$$

P8.19 $U_i + K_i + \Delta E_{\text{mech}} = U_f + K_f$: $\quad m_2gh - fh = \frac{1}{2}m_1v^2 + \frac{1}{2}m_2v^2$

$$f = \mu n = \mu m_1 g$$

$$m_2gh - \mu m_1gh = \frac{1}{2}(m_1 + m_2)v^2$$

$$v^2 = \frac{2(m_2 - \mu m_1)(hg)}{m_1 + m_2}$$

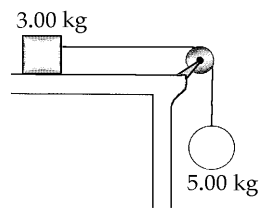

FIG. P8.19

$$v = \sqrt{\frac{2(9.80 \text{ m/s}^2)(1.50 \text{ m})[5.00 \text{ kg} - 0.400(3.00 \text{ kg})]}{8.00 \text{ kg}}} = \boxed{3.74 \text{ m/s}}$$

P8.21 (a) $\Delta K = \frac{1}{2}m(v_f^2 - v_i^2) = -\frac{1}{2}mv_i^2 = \boxed{-160 \text{ J}}$

(b) $\Delta U = mg(3.00 \text{ m})\sin 30.0° = \boxed{73.5 \text{ J}}$

(c) The mechanical energy converted due to friction is 86.5 J

$$f = \frac{86.5 \text{ J}}{3.00 \text{ m}} = \boxed{28.8 \text{ N}}$$

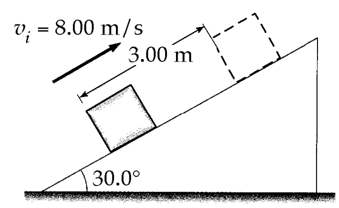

FIG. P8.21

(d) $f = \mu_k n = \mu_k mg\cos 30.0° = 28.8 \text{ N}$

$$\mu_k = \frac{28.8 \text{ N}}{(5.00 \text{ kg})(9.80 \text{ m/s}^2)\cos 30.0°} = \boxed{0.679}$$

P8.23 (a) $(K+U)_i + \Delta E_{\text{mech}} = (K+U)_f$:

$$0 + \frac{1}{2}kx^2 - f\Delta x = \frac{1}{2}mv^2 + 0$$

$$\frac{1}{2}(8.00 \text{ N/m})(5.00\times10^{-2} \text{ m})^2 - (3.20\times10^{-2} \text{ N})(0.150 \text{ m}) = \frac{1}{2}(5.30\times10^{-3} \text{ kg})v^2$$

$$v = \sqrt{\frac{2(5.20\times10^{-3} \text{ J})}{5.30\times10^{-3} \text{ kg}}} = \boxed{1.40 \text{ m/s}}$$

(b) When the spring force just equals the friction force, the ball will stop speeding up. Here $|\vec{\mathbf{F}}_s| = kx$; the spring is compressed by

$$\frac{3.20\times10^{-2}\ \text{N}}{8.00\ \text{N/m}} = 0.400\ \text{cm}$$

and the ball has moved

$$5.00\ \text{cm} - 0.400\ \text{cm} = \boxed{4.60\ \text{cm from the start}}$$

(c) Between start and maximum speed points, w

$$\frac{1}{2}kx_i^2 - f\Delta x = \frac{1}{2}mv^2 + \frac{1}{2}kx_f^2$$

$$\frac{1}{2}8.00\left(5.00\times10^{-2}\right)^2 - \left(3.20\times10^{-2}\right)\left(4.60\times10^{-2}\right)$$

$$= \frac{1}{2}\left(5.30\times10^{-3}\right)v^2 + \frac{1}{2}8.00\left(4.00\times10^{-3}\right)^2$$

$$v = \boxed{1.79\ \text{m/s}}$$

P8.29 $\text{Power} = \frac{W}{t}$

$$P = \frac{mgh}{t} = \frac{(700\ \text{N})(10.0\ \text{m})}{8.00\ \text{s}} = \boxed{875\ \text{W}}$$

P8.33 $energy = power \times time$

For the 28.0 W bulb:

$$\text{Energy used } = (28.0\ \text{W})\left(1.00\times10^4\ \text{h}\right) = 280\ \text{kilowatt}\cdot\text{hrs}$$

$$\text{total cost } = \$17.00 + (280\ \text{kWh})(\$0.080/\text{kWh}) = \$39.40$$

For the 100 W bulb:

$$\text{Energy used } = (100\ \text{W})\left(1.00\times10^4\ \text{h}\right) = 1.00\times10^3\ \text{kilowatt}\cdot\text{hrs}$$

$$\#\ \text{bulb used } = \frac{1.00\times10^4\ \text{h}}{750\ \text{h/bulb}} = 13.3$$

$$\text{total cost } = 13.3(\$0.420) + \left(1.00\times10^3\ \text{kWh}\right)(\$0.080/\text{kWh}) = \$85.60$$

Savings with energy-efficient bulb $= \$85.60 - \$39.40 = \boxed{\$46.2}$.

P8.35 The energy of the car is $E = \frac{1}{2}mv^2 + mgy$

$E = \frac{1}{2}mv^2 + mgd\sin\theta$ where d is the distance it has moved along the track.

$$P = \frac{dE}{dt} = mv\frac{dv}{dt} + mgv\sin\theta$$

(a) When speed is constant,

$\mathcal{P} = mgv\sin\theta = 950\text{ kg}\left(9.80\text{ m/s}^2\right)\left(2.20\text{ m/s}\right)\sin 30° = \boxed{1.02\times10^4\text{ W}}$

(b) $\frac{dv}{dt} = a = \frac{2.2\text{ m/s}-0}{12\text{ s}} = 0.183\text{ m/s}^2$

Maximum power is injected just before maximum speed is attained:

$\mathcal{P} = mva + mgv\sin\theta = 950\text{ kg}\left(2.2\text{ m/s}\right)\left(0.183\text{ m/s}^2\right) + 1.02\times10^4\text{ W} = \boxed{1.06\times10^4\text{ W}}$

(c) At the top end,

$\frac{1}{2}mv^2 + mgd\sin\theta = 950\text{ kg}\left(\frac{1}{2}(2.20\text{ m/s})^2 + \left(9.80\text{ m/s}^2\right)1\,250\text{ m}\sin 30°\right) = \boxed{5.82\times10^6\text{ J}}$

P8.55

$\Delta E_{\text{mech}} = -f\Delta x$

$E_f - E_i = -f\cdot d_{BC}$

$\frac{1}{2}kx^2 - mgh = -\mu mgd_{BC}$

$\mu = \frac{mgh - \frac{1}{2}kx^2}{mgd_{BC}} = \boxed{0.328}$

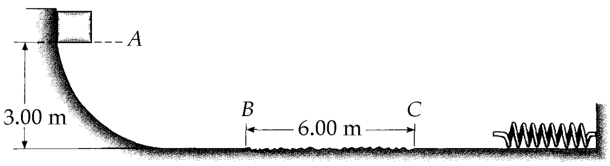

FIG. P8.55

P8.59 (a) Initial compression of spring: $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$

$\frac{1}{2}(450\text{ N/m})(\Delta x)^2 = \frac{1}{2}(0.500\text{ kg})(12.0\text{ m/s})^2$

Therefore, $\Delta x = \boxed{0.400\text{ m}}$

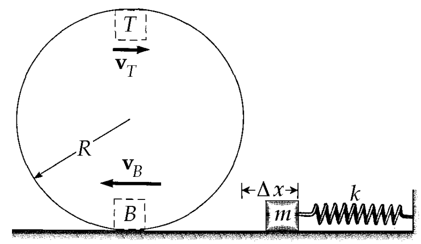

FIG. P8.59

(b) Speed of block at top of track: $\Delta E_{\text{mech}} = -f\Delta x$

$$\left(mgh_T + \frac{1}{2}mv_T^2\right) - \left(mgh_B + \frac{1}{2}mv_B^2\right) = -f(\pi R)$$

$$(0.500\text{ kg})\left(9.80\text{ m/s}^2\right)(2.00\text{ m}) + \frac{1}{2}(0.500\text{ kg})v_T^2 - \frac{1}{2}(0.500\text{ kg})(12.0\text{ m/s})^2 = -(7.00\text{ N})(\pi)(1.00\text{ m})$$

$0.250v_T^2 = 4.21$

$\therefore v_T = \boxed{4.10\text{ m/s}}$

(c) Does block fall off at or before top of track? Block falls if $a_c < g$

$$a_c = \frac{v_T^2}{R} = \frac{(4.10)^2}{1.00} = 16.8\text{ m/s}^2$$

Therefore $a_c > g$ and the $\boxed{\text{block stays on the track}}$.