17.17: \[ aL_0 \Delta T = (1.2 \times 10^{-5} \, (C^\circ)^{-1}) (1410 \, m) (18.0 \, C - (-5.0) \, C) = +0.39 \, m. \]

17.37: \[ 210^\circ C - 20^\circ C \|$\{1.60 \, kg \|$910 \, J/kg \cdot K\} + \{0.30 \, kg \|$470 \, J/kg \cdot K\} = 3.03 \times 10^5 \, J. \]

17.39: \[ 85.0^\circ C - 20.0^\circ C \|$\{1.50 \, kg \|$910 \, J/kg \cdot K\} + \{1.80 \, kg \|$4190 \, J/kg \cdot K\} = 5.79 \times 10^5 \, J. \]

17.41: a) \[ c = \frac{Q}{m \Delta T} = \frac{\{120 \, s \|$65.0 \, W\}}{\{0.780 \, kg \|$22.54 \, ^\circ C - 18.55 \, ^\circ C\}} = 2.51 \times 10^3 \, J/kg \cdot K. \]

\[ \text{b) An overestimate; the heat } Q \text{ is in reality less than the power times the time interval.} \]

17.45: a) \[ Q_{\text{water}} + Q_{\text{metal}} = 0 \]
\[ m_{\text{water}} c_{\text{water}} \Delta T_{\text{water}} + m_{\text{metal}} c_{\text{metal}} \Delta T_{\text{metal}} = 0 \]
\[ \{1.00 \, kg \|$4190 \, J/kg \cdot K\} \{2.0 \, ^\circ C\} + \{0.500 \, kg \|$c_{\text{metal}} \} \{-78.0 \, ^\circ C\} = 0 \]
\[ c_{\text{metal}} = 215 \, J/kg \cdot K \]

\[ \text{b) Water has a larger specific heat capacity so stores more heat per degree of temperature change.} \]

\[ \text{c) If some heat went into the styrofoam then } Q_{\text{metal}} \text{ should actually be larger than in part (a), so the true } c_{\text{metal}} \text{ is larger than we calculated; the value we calculated would be smaller than the true value.} \]

17.49: \[ Q = m (c_{\text{ice}} \Delta T_{\text{ice}} + L_f + c_{\text{water}} \Delta T_{\text{water}} + L_V) \]
\[ = (12.0 \times 10^{-3} \, kg) \]
\[ (2100 \, J/kg \cdot K) \{10.0 \, ^\circ C\} + 334 \times 10^3 \, J/kg \]
\[ + (100 \, ^\circ C) \{4190 \, J/kg \cdot K\} + 2256 \times 10^3 \, J/kg \]
17.55: The mass of water that the camel saves is

$$\frac{M c \Delta T}{L_v} = \frac{(400 \text{ kg})(3480 \text{ J/kg} \cdot \text{K})(6.0 \text{ K})}{(2.42 \times 10^6 \text{ J/kg})} = 3.45 \text{ kg},$$

which is a volume of 3.45 L.

17.67: (Although it may be easier for some to solve for the heat flow per unit area, part (b), the method presented here follows the order in the text.) a) See Example 17.13; as in that example, the area may be divided out, and solving for temperature $T$ at the boundary,

$$T = \frac{\left| k_{\text{foam}}/L_{\text{foam}} \right| T_{\text{in}} + \left| k_{\text{wood}}/L_{\text{wood}} \right| T_{\text{out}}}{N \left| k_{\text{foam}}/L_{\text{foam}} \right| + \left| k_{\text{wood}}/L_{\text{wood}} \right|}
\frac{\left| 0.010 \text{ W/m} \cdot \text{K} / |2.2 \text{ cm}|(19.0 ^\circ \text{C}) + \left| 0.080 \text{ W/m} \cdot \text{K} / |3.0 \text{ cm}| \right| -10.0 ^\circ \text{C} \right|}{\left| 0.010 \text{ W/m} \cdot \text{K} / |2.2 \text{ cm}| + \left| 0.080 \text{ W/m} \cdot \text{K} / |3.0 \text{ cm}| \right|}

= -5.8 ^\circ \text{C}.$$

Note that the conversion of the thickness to meters was not necessary. b) Keeping extra figures for the result of part, (a), and using that result in the temperature difference across either the wood or the foam gives

$$\frac{H_{\text{foam}}}{A} = \frac{H_{\text{wood}}}{A} = \left| 0.010 \text{ W/m} \cdot \text{K} \right| \frac{19.0 ^\circ \text{C} - \left| -5.767 ^\circ \text{C} \right|}{2.2 \times 10^{-2} \text{ m}}
\frac{\left| -5.767 ^\circ \text{C} - \left| -10.0 ^\circ \text{C} \right| \right|}{3.0 \times 10^{-2} \text{ m}}

= 11 \text{ W/m}^2.

17.79: a) normal melting point of mercury: $-30 ^\circ \text{C} = 0.0 ^\circ \text{M}$

normal boiling point of mercury: $357 ^\circ \text{C} = 100.0 ^\circ \text{M}$

$100 ^\circ \text{M} = 396 ^\circ \text{C}$ so $1 ^\circ \text{M} = 3.96 ^\circ \text{C}$

Zero on the M scale is $-39$ on the C scale, so to obtain $T_C$ multiple $T_M$ by 3.96 and then subtract 39. $T_C = 3.96 T_M - 39 ^\circ$

Solving for $T_M$ gives $T_M = \frac{1}{3.96} (T_C + 39 ^\circ)$

The normal boiling point of water is $100 ^\circ \text{C}; T_M = \frac{1}{3.96} (100 ^\circ + 39 ^\circ) = 35.1 ^\circ \text{M}$

b) $10.0 ^\circ \text{M} = 39.6 ^\circ \text{C}$

18.3: For constant temperature, Eq. (18.6) becomes

$$p_2 = p_1 \frac{V_1}{V_2} = (3.40 \text{ atm})(0.110/0.390) = 0.96 \text{ atm}.$$
18.11: \[ V_2 = V_1 \frac{T_2}{T_1} = (0.600 \text{ L})(77.3/292.15) = 0.159 \text{ L}. \]

18.14: a) \[ \frac{V_2}{V_1} = \frac{p_1 T_2}{p_2 T_1} = (3.50)(\frac{296}{277}) = 3.74. \] b) Lungs cannot withstand such a volume change; breathing is a good idea.

18.24: \[ N = nN_A = \frac{pV}{RT}N_A \]
\[ = \left( \frac{9.119 \times 10^{-9} \text{ Pa}}{8.3145 \text{ J/mol} \cdot \text{K}} \right) \left( \frac{1.00 \times 10^{-6} \text{ m}^3}{300 \text{ K}} \right) \left( 6.023 \times 10^{23} \text{ molecules/mol} \right) \]
\[ = 2.20 \times 10^6 \text{ molecules}. \]

18.25: a) \[ p = \frac{nRT}{V} = \frac{N RT}{VN_A} = \left( 80 \times 10^3 \text{ molecules/L} \right) \left( 0.08206 \text{ L-atm/mol} \cdot \text{K} \right) \left( \frac{7500}{6.023 \times 10^{23} \text{ molecules/mol}} \right) \]
\[ = 8.2 \times 10^{-17} \text{ atm}, \]
about \( 8.2 \times 10^{-12} \text{ Pa}. \) This is much lower, by a factor of a thousand, than the pressures considered in Exercise 18.24. b) Variations in pressure of this size are not likely to affect the motion of a starship.

18.29: a) \[ V = ml/\rho = n M / p = [5.00 \text{ mol}] \left( 18.0 \text{ g/mol} \right) / \left( 1.00 \text{ g/cm}^3 \right) = 90.0 \text{ cm}^3 = 9.00 \times 10^{-5} \text{ m}^3 \]
b) See Exercise 18.28;
\[ \left( \frac{V}{N} \right)^{1/3} = \left( \frac{V}{nN_A} \right)^{1/3} = \left( \frac{9.00 \times 10^{-5} \text{ m}^3}{5.00 \text{ mol} \times 6.023 \times 10^{23} \text{ molecules/mol}} \right)^{1/3} \]
\[ = 3.10 \times 10^{-10} \text{ m}. \]
c) This is comparable to the size of a water molecule.

18.32: (Many calculators have statistics functions that are preprogrammed for such calculations as part of a statistics application. The results presented here were done on such a calculator.) a) With the multiplicity of each score denoted by \( n_i, \) the average is \[ \frac{1}{150} \sum n_i x_i = 54.6 \]
b) \[ \left[ \frac{1}{150} \sum n_i x_i^2 \right]^{1/2} = 61.1. \] (Extra significant figures are warranted because the sums are known to higher precision.)

18.35: a) \[ m = m_p + m_n = 3.348 \times 10^{-27} \text{ kg}; \quad T = 300 \times 10^6 \text{ K} \]
\[ v_{\text{rms}} = \sqrt{3kT/m} = 1.9 \times 10^6 \text{ m/s}; \quad v_{\text{rms}}c = 0.64 \]

b) \[ T = mv_{\text{rms}}^2/3k \]

For \( v_{\text{rms}} = 3.0 \times 10^7 \text{ m/s}, \quad T = 7.3 \times 10^{10} \text{ K} \]

18.40:  
\[ a) \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.381 \times 10^{-23} \text{ J/K})(300 \text{ K})}{3.00 \times 10^{-16} \text{ kg}}} = 6.44 \times 10^{-3} \text{ m/s.} \]  
b) If the particle is in thermal equilibrium with its surroundings, its motion will depend only on the surrounding temperature, not the mass of the individual particles.

18.51: The temperature of \( 0.00^\circ \text{C} \) is just below the triple point of water, and so there will be no liquid. Solid ice and water vapor at \( 0.00^\circ \text{C} \) will be in equilibrium.

19.3:

\[ pV = nRT \]

\( T \) constant, so when \( p \) increases, \( V \) decreases.

b) From example 19.1, \( W = nRT \ln(p_1/p_2) \) for an isothermal process.

\[ T = 53.0 + 273.15 = 326.15 \text{ K} \]

\[ W = -1.49 \times 10^4 \text{ J} \]  
The work done by the gas is negative because the volume decreases.

19.10:  
a) \( p\Delta V = (1.80 \times 10^5 \text{ Pa})(0.210 \text{ m}^2) = 3.78 \times 10^4 \text{ J.} \)

b) \( \Delta U = Q - W = 1.15 \times 10^5 \text{ J} - 3.78 \times 10^4 \text{ J} = 7.72 \times 10^4 \text{ J.} \)

c) The relations \( W = p\Delta V \) and \( \Delta U = Q - W \) hold for any system.

19.22:  
a) \( nC_v \Delta T = (0.0100 \text{ mol})(12.47 \text{ J/mol-K})(40.0 \text{ C}^\circ) = 4.99 \text{ J.} \)
b) \[ nC_p \Delta T = (0.0100 \text{ mol})(20.78 \text{ J/mol·K})(40.0 \text{ °C}) = 8.31 \text{ J}. \]

b) In the first process, \( W = 0 \) but in the second \( W > 0 \). \( \Delta U \) is the same for both, and so \( Q \) is larger for the second. d) For an ideal gas, \( \Delta U = nC_v \Delta T = 4.99 \text{ J} \) for both parts (a) and (b).

19.33: a)

b) (Use \( \gamma = 1.400 \), as in Example 19.6) From Eq. (19.22),

\[ T_2 = T_1 \left( \frac{V_1}{V_2} \right)^{\gamma-1} = \left( \frac{293.15 \text{ K}}{11.1} \right)^{0.400} = 768 \text{ K} = 495 \text{ °C} \]

and from Eq. (19.24), \( p_2 = p_1 \left( \frac{V_1}{V_2} \right)^\gamma = \left( \frac{1.00 \text{ atm}}{11.1} \right)^{1.400} = 29.1 \text{ atm} \).
20.1: a) \(\frac{2200}{J+4300} = \frac{J=6500}{J}\) b) \(\frac{2200}{6500} = 0.338 = 33.8\%\).

20.3: a) \(\frac{3700}{16,100} = 0.230 = 23.0\%\).

b) \(16,100 J - 3700 J = 12,400 J\).

c) \(\frac{16,100 J}{4.60 \times 10^4 J/kg} = 0.350\ g\).

d) \((3700 J)(60.0/\text{s}) = 222\ kW = 298\ hp\).

20.8: a) From Eq. (20.6), \(e = 1 - r^{1-\gamma} = 1 - (8.8)^{-0.40} = 0.58 = 58\%\).

b) \(1 - (9.6)^{-0.40} = 60\%,\ an\ increase\ of\ 2\%.\ If\ more\ figures\ are\ kept\ for\ the\ efficiencies,\ the\ difference\ is\ 1.4\%\).

20.19: The total work that must be done is

\[ W_{\text{tot}} = mgv = (500 \ \text{kg})(9.80 \ m/s^2)(100 \ m) = 4.90 \times 10^5 \ J \]

\[ Q_H = 250 \ J \quad \text{Find } Q_C \text{ so can calculate work } W \text{ done each cycle:} \]

\[ Q_C = -T_C \quad Q_H = \frac{-T_C}{T_H} \]

\[ Q_C = -(T_C/T_H)Q_H = -(250 \ J)[(373.15 \ K)/(773.15 \ K)] = -120.7 \ J \]

\[ W = Q_C + Q_H = 129.3 \ J \]

The number of cycles required is

\[ \frac{W_{\text{tot}}}{W} = \frac{4.09 \times 10^5 \ J}{129.3 \ J} = 3790 \ \text{cycles} \]

20.24: a) \(\frac{Q}{T_C} = \frac{mL_f}{T_C} = \frac{0.350 \ \text{kg}[334 \times 10^3 J/kg]}{273.15 \ K} = 428 \ J/K\).

b) \(-1.17 \times 10^5 \ J = -392 J/K\).

c) \(\Delta S = 428 \ J/K + (-392 \ J/K) = 36 \ J/K\). (If more figures are kept in the intermediate calculations, or if \(\Delta S = Q((1/273.15 \ K) - (1/298.15 \ K))\) is used, \(\Delta S = 35.6 \ J/K\).

20.25: a) Heat flows out of the 80.0° C water into the ocean water and the 80.0° C water cools to 20.0° C (the ocean warms, very, very slightly). Heat flow for an isolated system is always in this direction, from warmer objects into cooler objects, so this process is irreversible.

c) 0.100 kg of water goes form 80.0° C to 20.0° C and the heat flow is

\[ Q = mc \Delta T = (0.100 \ kg)(4190 \ J/kg \cdot K)(-60.0 \ C) = -2.154 \times 10^4 \ J \]

This \(Q\) comes out of the 0.100 kg of water and goes into the ocean. For the 0.100 kg of water,

\[ \Delta S = mc \ln(T_2/T_1) = (0.100 \ kg)(4190 \ J/kg \cdot K) \ln(293.15/353.15) = -78.02 \]

For the ocean the heat flow is \(Q = -2.154 \times 10^4 \ J\) and occurs at constant \(T\):
\[ \Delta S = \frac{Q}{T} = 2.154 \times 10^4 \frac{J}{K} = +85.76 \ J/K \]
\[ \Delta S_{\text{net}} = \Delta S_{\text{water}} + \Delta S_{\text{ocean}} = -78.02 \ J/K + 85.76 \ J/K = +7.7 \ J/K \]

**20.34:**

a) On the average, each half of the box will contain half of each type of molecule, 250 of nitrogen and 50 of oxygen.  
b) See Example 20.11. The total change in entropy is

\[ \Delta S = k N_1 \ln(2) + k N_2 \ln(2) = (N_1 + N_2)k \ln(2) \]

\[ = (600)(1.381 \times 10^{-23} \ J/K) \ln(2) = 5.74 \times 10^{-21} \ J/K. \]

c) See also Exercise 20.36. The probability is \[ \frac{1}{2} \times \frac{1}{2} \times 600 = 2.4 \times 10^{-181}, \]
and is not likely to happen.

The numerical result for part (c) above may not be obtained directly on some standard calculators. For such calculators, the result may be found by taking the log base ten of 0.5 and multiplying by 600, then adding 181 and then finding 10 to the power of the sum. The result is then \[ 10^{-181} \times 10^{0.87} = 2.4 \times 10^{-181}. \]