2-38 Initially, the absolute pressure in the tire is

\[ P_1 = P_g + P_{am} = 210 + 100 = 310 \text{ kPa} \]

Treating air as an ideal gas and assuming the volume of the tire to remain constant, the final pressure in the tire can be determined from

\[ \frac{PV_1}{T_1} = \frac{PV_2}{T_2} \rightarrow P_2 = \frac{T_2}{T_1} P_1 = \frac{323 \text{ K}}{298 \text{ K}} (310 \text{ kPa}) = 336 \text{ kPa} \]

Thus the pressure rise is

\[ \Delta P = P_2 - P_1 = 336 - 310 = 26 \text{ kPa} \]

The amount of air that needs to be bled off to restore pressure to its original value is

\[ m_1 = \frac{PV}{RT_1} = \frac{(310 \text{ kPa})(0.025 \text{ m}^3)}{(0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(298 \text{ K})} = 0.0906 \text{ kg} \]

\[ m_2 = \frac{PV}{RT_2} = \frac{(310 \text{ kPa})(0.025 \text{ m}^3)}{(0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(323 \text{ K})} = 0.0836 \text{ kg} \]

\[ \Delta m = m_1 - m_2 = 0.0906 - 0.0836 = 0.0070 \text{ kg} \]

2-41E Treating air as an ideal gas, the initial volume and the final mass in the tank are determined to be

\[ V = \frac{m_1 RT_1}{P_1} = \frac{(20 \text{ lbm})(0.3705 \text{ psia} \cdot \text{ft}^3/\text{lbm} \cdot \text{R})(530 \text{ R})}{20 \text{ psia}} = 196.4 \text{ ft}^3 \]

\[ m_2 = \frac{P_2 V}{RT_2} = \frac{(35 \text{ psia})(196.4 \text{ ft}^3)}{(0.3705 \text{ psia} \cdot \text{ft}^3/\text{lbm} \cdot \text{R})(550 \text{ R})} = 33.73 \text{ lbm} \]

Thus the amount of air added is

\[ \Delta m = m_2 - m_1 = 33.73 - 20.0 = 13.73 \text{ lbm} \]

2-50 The gas constant, the critical pressure, and the critical temperature of water are, from Table A-1,

\[ R = 0.4615 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K}, \quad T_{cr} = 647.3 \text{ K}, \quad P_{cr} = 22.09 \text{ MPa} \]

(a) From the ideal gas equation of state,

\[ v = \frac{RT}{P} = \frac{(0.4615 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(498 \text{ K})}{1,600 \text{ kPa}} = 0.14364 \text{ m}^3/\text{kg} \quad (8.1\% \text{ error}) \]

(b) From the compressibility chart (Fig. A-13),

\[ \begin{align*}
P_R &= \frac{P}{P_{cr}} = \frac{1.6 \text{ MPa}}{22.09 \text{ MPa}} = 0.072 \\
T_R &= \frac{T}{T_{cr}} = \frac{498 \text{ K}}{647.3 \text{ K}} = 0.769
\end{align*} \]

\[ Z = 0.935 \]

Thus,

\[ v = (Z)(v_{ideal}) = (0.935)(0.14364 \text{ m}^3/\text{kg}) = 0.13430 \text{ m}^3/\text{kg} \quad (1.1\% \text{ error}) \]
2-53E The critical pressure, and the critical temperature of oxygen are, from Table A-1E,

\[ T_{cr} = 278.6 \text{ R} \quad \text{and} \quad P_{cr} = 736 \text{ psia} \]

From the compressibility chart (Fig. A-13),

\[ \begin{align*}
    P_R &= \frac{P}{P_{cr}} = \frac{400 \text{ psia}}{736 \text{ psia}} = 0.543 \\
    T_R &= \frac{T}{T_{cr}} = \frac{280 \text{ R}}{278.6 \text{ R}} = 1.005 \\
    Z &= 0.79
\end{align*} \]

Then the error involved can be determined from

\[ \text{error} = \frac{v - v_{ideal}}{v} = 1 - \frac{1}{Z} = 1 - \frac{1}{0.79} = -26.6\% \]

Thus the claim is false.

3-36 Nitrogen at specified conditions can be treated as an ideal gas. Then the boundary work for this isothermal process can be determined from

\[ W_b = \int P \, dV = P_1 V_1 \ln \frac{V_2}{V_1} = \frac{P_1}{P_2} \ln \frac{P_1}{P_2} \]

\[ = (150 \text{ kPa})(0.2 \text{ m}^3) \left( \ln \frac{150 \text{ kPa}}{800 \text{ kPa}} \right) \left( \frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right) \]

\[ = -50.2 \text{ kJ} \]

3-42 The boundary work done during this process is

\[ W_b = \int P \, dV = \int \left( \frac{a}{V^2} \right) dV = -a \left( \frac{1}{V} - \frac{1}{V_1} \right) \]

\[ = -(8 \text{ kPa} \cdot \text{m}^6) \left( \frac{1}{0.1 \text{ m}^3} - \frac{1}{0.3 \text{ m}^3} \right) \left( \frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right) \]

\[ = -53.3 \text{ kJ} \]

3-53 (a) The conservation of energy equation for the cycle is

\[ Q - W = 0 \]

\[ 40 - (-60) + Q_2 - (-45) = 0 \]

\[ Q_2 = -25 \text{ kJ} \]

(b) Net heat transfer and the net work done during this cycle are

\[ Q_{net} = Q_1 + Q_2 = 40 - 25 = 15 \text{ kJ} \]

\[ W_{net} = W_1 + W_2 = 60 - 15 = 15 \text{ kJ} \]
3-55 The total cooling load of the room is determined from

\[ \dot{Q}_{\text{cool}} = \dot{Q}_{\text{lights}} + \dot{Q}_{\text{people}} + \dot{Q}_{\text{heat gain}} \]

where

\[ \dot{Q}_{\text{lights}} = 10 \times 100 \text{ W} = 1 \text{ kW} \]
\[ \dot{Q}_{\text{people}} = 40 \times 360 \text{ kJ/h} = 4 \text{ kW} \]
\[ \dot{Q}_{\text{heat gain}} = 15,000 \text{ kJ/h} = 4.17 \text{ kW} \]

Substituting,

\[ \dot{Q}_{\text{cool}} = 1 + 4 + 4.17 = 9.17 \text{ kW} \]

Thus the number of air-conditioning units required is

\[ \frac{9.17 \text{ kW}}{5 \text{ kW/unit}} = 1.83 \rightarrow 2 \text{ units} \]

3-64 (a) Using the empirical relation for \( C_p(T) \) from Table A-2c,

\[ C_p = a + bT + cT^2 + dT^3 \]

where \( a = 28.90 \), \( b = -0.1571 \times 10^{-2} \), \( c = 0.08081 \times 10^{-4} \), and \( d = -2.873 \times 10^{-9} \). Then,

\[ \Delta h = \int_{T_1}^{T_2} C_p(T) \, dT = \int_{T_1}^{T_2} \left[ a + bT + cT^2 + dT^3 \right] dT \]
\[ = a(T_2 - T_1) + \frac{1}{2} b(T_2^2 - T_1^2) + \frac{1}{3} c(T_2^3 - T_1^3) + \frac{1}{4} d(T_2^4 - T_1^4) \]
\[ = 28.90(1000 - 600) + \frac{1}{2} (0.1571 \times 10^{-2})(1000^2 - 600^2) \]
\[ + \frac{1}{3} (0.08081 \times 10^{-4})(1000^3 - 600^3) - \frac{1}{4} (2.873 \times 10^{-9})(1000^4 - 600^4) \]
\[ = 12,544 \text{ kJ/kmol} \]

\[ \Delta h = \frac{\Delta h}{M} = \frac{12,544 \text{ kJ/kmol}}{28.013 \text{ kg/kmol}} = 447.8 \text{ kJ/kg} \]

(b) Using constant \( C_p \) value from Table A-2b at the average temperature of 800 K,

\[ C_{p,\text{ave}} = C_p @ 800 \text{ K} = 1.121 \text{ kJ/kg} \cdot \text{K} \]

\[ \Delta h = C_{p,\text{ave}}(T_2 - T_1) = (1.121 \text{ kJ/kg} \cdot \text{K})(1000 - 600) \text{K} = 448.4 \text{ kJ/kg} \]

(c) Using constant \( C_p \) value from Table A-2a at room temperature,

\[ C_{p,\text{ave}} = C_p @ 300 \text{ K} = 1.039 \text{ kJ/kg} \cdot \text{K} \]

\[ \Delta h = C_{p,\text{ave}}(T_2 - T_1) = (1.039 \text{ kJ/kg} \cdot \text{K})(1000 - 600) \text{K} = 415.6 \text{ kJ/kg} \]
3-68E  (a) At specified conditions air can be treated as an ideal gas. Then the volume of the tank can be determined from the ideal gas relation,

\[ V = \frac{mRT_1}{P_1} = \frac{(20 \text{ lbm})(0.3705 \text{ psia} \cdot \text{ft}^3 / \text{lbm} \cdot \text{R})(540 \text{ R})}{50 \text{ psia}} = 80.0 \text{ ft}^3 \]

(b) We take the air in the tank as our system. This is a closed system since no mass enters or leaves. The conservation of energy equation for this case reduces to

\[ Q - W^{70} = \Delta U + \Delta KE^{70} + \Delta PE^{70} \]

\[ Q = m(u_2 - u_1) \equiv mC_v(T_2 - T_1) \]

The final temperature of air is

\[ \frac{PVT_1}{T_1} = \frac{PVT_2}{T_2} \implies T_2 = \frac{P_2}{P_1} T_1 = 2 \times (540 \text{ R}) = 1080 \text{ R} \]

The specific heat of air at the average temperature of \( T_{ave} = (540 + 1080)/2 = 810 \text{ R} = 350^\circ\text{F} \) is, from Table A-2Ea, \( C_{v,ave} = 0.175 \text{ Btu/lbm.R} \). Substituting,

\[ Q = (20 \text{ lbm})(0.175 \text{ Btu/lbm.R})(1080 - 540) \text{ R} = 1890 \text{ Btu} \]

3-70  At specified conditions air can be treated as an ideal gas. We take the air in the room as our system. Assuming the room is well-sealed and no air leaks out, we have a constant volume closed system. The conservation of energy equation for this case reduces to

\[ Q^{70} - W_e = \Delta U + \Delta KE^{70} + \Delta PE^{70} \]

\[ -W_e = m(u_2 - u_1) = mC_{v,ave}(T_2 - T_1) \]

or,

\[ -W_e \Delta T = mC_{v,ave}(T_2 - T_1) \]

The mass of air is

\[ V = 4 \times 5 \times 6 = 120 \text{ m}^3 \]

\[ m = \frac{PV}{RT_1} = \frac{(100 \text{ kPa})(120 \text{ m}^3)}{(0.287 \text{ kPa} \cdot \text{m}^3 / \text{kg} \cdot \text{K})(280 \text{ K})} = 149.3 \text{ kg} \]

Using \( C_v \), value at room temperature from Table A-2a,

\[ -W_e(15 \times 60 \text{ s}) = (149.3 \text{ kg})(0.718 \text{ kJ} / \text{kg} \cdot ^\circ\text{C})(23 - 7)^\circ\text{C} = -1.91 \text{ kW} \]

The negative sign indicates electrical work is done on the system.

3-74  We take the entire tank as our system. This is a constant volume closed system since no mass enters or leaves the system. The conservation of energy equation for this ideal gas reduces to

\[ Q^{70} - W^{70} = \Delta U + \Delta KE^{70} + \Delta PE^{70} \]

Thus,

\[ T_3 = T_1 = 50^\circ\text{C} \]

and

\[ \frac{PV_1}{T_1} = \frac{PV_2}{T_2} \implies P_2 = \frac{V_2}{V_1} P_1 = \frac{1}{2} (800 \text{ kPa}) = 400 \text{ kPa} \]
3-85 We take the air contained within the piston-cylinder device as our system and since no mass is crossing the system boundaries, it is a closed system. Under the given conditions, the air may be assumed to behave as an ideal gas. The initial and the final volumes and the final temperature of air are determined from

\[
V_1 = \frac{mRT_1}{P_1} = \frac{(3 \text{ kg})(0.287 \text{ kPa} \cdot \text{m}^3 / \text{kg} \cdot \text{K})(300 \text{ K})}{200 \text{ kPa}} = 1.29 \text{ m}^3
\]

\[
V_3 = 2V_1 = 2 \times 1.29 = 2.58 \text{ m}^3
\]

\[
\frac{P_1V_1}{T_1} = \frac{P_3V_3}{T_3} \quad \rightarrow \quad T_3 = \frac{P_3V_3}{P_1V_1}T_1 = \frac{400 \text{ kPa}}{200 \text{ kPa}} \times 2 \times (300 \text{ K}) = 1200 \text{ K}
\]

No work is done during process 2-3 since \( V_2 = V_3 \). The pressure remains constant during process 1-2 and the work done during this process is

\[
W_b = \int_1^2 P \, dV = P_1(V_2 - V_1) = (200 \text{ kPa})(2.58 - 1.29) \text{m}^3 \left( \frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right) = 258 \text{ kJ}
\]

The total heat transfer is determined from the 1st law relation,

\[
Q - W_b = \Delta U + \Delta KE^{70} + \Delta PE^{70}
\]

\[
Q = m(u_f - u_i) + W_b \equiv mC_v(T_f - T_i) + W_b
\]

The specific heat of air at the average temperature of \( T_{\text{ave}} = (300 + 1200)/2 = 750 \text{ K} \) is, from Table A-2b, \( C_{\text{ave}} = 0.800 \text{ kJ/kg.K} \). Substituting

\[
Q = (3 \text{ kg})(0.800 \text{ kJ/kg.K})(1200 - 300) \text{ K} + 258 \text{ kJ} = 2418 \text{ kJ}
\]

3-90 We take the iron block and the water as our system. Then the conservation of energy equation for this process reduces to

\[
Q^{70} - W_b^{70} - W_{pw} = \Delta U + \Delta KE^{70} + \Delta PE^{70} \quad \rightarrow \quad -W_{pw} = \Delta U
\]

or,

\[
-W_{pw} = \Delta U_{\text{iron}} + \Delta U_{\text{water}}
\]

or,

\[
-W_{pw} = [mC(T_f - T_i)]_{\text{iron}} + [mC(T_f - T_i)]_{\text{water}}
\]

where

\[
m_{\text{water}} = \rho V = (1000 \text{ kg} / \text{m}^3)(0.08 \text{ m}^3) = 80 \text{ kg}
\]

\[
W_{pw} = W_{pw} \Delta t = (0.2 \text{ kJ/s})(25 \times 60 \text{ s}) = 300 \text{ kJ}
\]

Using specific heat values for iron and liquid water from Table A-3b and substituting,

\[
-(300 \text{ kJ}) = m_{\text{iron}}(0.45 \text{ kJ/kg°C})(27 - 90)\text{°C} + (80 \text{ kg})(4.184 \text{ kJ/kg°C})(27 - 20)\text{°C} = 0
\]

\[
m_{\text{iron}} = 72.1 \text{ kg}
\]