Problem 5.47E
Saturated R-134a vapor at 100°F is condensed at a constant pressure to a saturated liquid in a closed piston-cylinder device. Determine the heat transfer and work done during the process, in BTU/lb.

\[ Q - W = \Delta U = m \left( u_2 - u_1 \right) \]

or \[ q = W + \left( u_2 - u_1 \right) \] (per unit mass)

The properties at the initial and final states are (Table A-11E)

\[ T_1 = 100^\circ F \quad \nu_1 = \nu_g = 0.34045 \text{ ft}^3/\text{lbm} \]
\[ x_1 = 1 \quad \nu_1 = \nu_g = 107.45 \text{ Btu/lbm} \]
\[ T_2 = 100^\circ F \quad \nu_2 = \nu_f = 0.01386 \text{ ft}^3/\text{lbm} \]
\[ x_2 = 0 \quad \nu_2 = \nu_f = 44.768 \text{ Btu/lbm} \]

Also from Table A-11E,

\[ P_1 = P_2 = 138.93 \text{ psia} \]
\[ u_{fg} = 62.683 \text{ Btu/lbm} \]
\[ h_{fg} = 71.080 \text{ Btu/lbm} \]

\[ w_{b,out} = \int_1^2 Pd\nu = P(\nu_2 - \nu_1) \]

\[ = (138.93 \text{ psia})(0.01386 - 0.34045) \text{ft}^3/\text{lbm} \left( \frac{1 \text{ Btu}}{5.404 \text{ psia} \cdot \text{ft}^3} \right) = \text{8.396 Btu/lbm} \]

\[ q = W + \left( u_2 - u_1 \right) = -8.396 + (44.768 - 107.45) \]

\[ = -71.08 \text{ BTU/lb} \]
Problem 5.65E
A rigid tank contains 20 lbm of air at 50 psia and 80°F. The air is then heated until its pressure doubles. Determine a) the volume of the tank, and b) the amount of heat transferred to the tank.

\[ V = \frac{mRT_1}{P_1} = \frac{(20 \text{ lbm})(0.3704 \text{ psia} \cdot \text{ft}^2/\text{lbm} \cdot \text{R})(540 \text{ R})}{50 \text{ psia}} = 80.0 \text{ ft}^3 \]

\[ \frac{E_{\text{in}} - E_{\text{out}}}{\text{Net energy transfer by heat, work, and mass}} = \frac{\Delta E_{\text{system}}}{\text{Change in internal, kinetic, potential, etc. energies}} \]

\[ Q_{\text{in}} = \Delta U \]

\[ Q_{\text{in}} = m(u_2 - u_1) = mc_v(T_2 - T_1) \]

The final temperature of air is

\[ \frac{P_1V}{T_1} = \frac{P_2V}{T_2} \rightarrow T_2 = \frac{P_2}{P_1} T_1 = 2 \times (540 \text{ R}) = 1080 \text{ R} \]

The internal energies are (Table A-21E)

\[ u_1 = u_{540 \text{ R}} = 92.04 \text{ Btu/lbm} \]

\[ u_2 = u_{1080 \text{ R}} = 186.93 \text{ Btu/lbm} \]

Substituting,

\[ Q_{\text{in}} = (20 \text{ lbm})(186.93 - 92.04) \text{Btu/lbm} = 1898 \text{ Btu} \]

**Alternative solutions** The specific heat of air at the average temperature 350°F is, from Table A-2Eb, \( c_{v,\text{avg}} = 0.175 \text{ Btu/lbm.R} \). Substituting,

\[ Q_{\text{in}} = (20 \text{ lbm})(0.175 \text{ Btu/lbm.R})(1080 - 540) \text{ R} = 1890 \text{ Btu} \]
Problem 5.66
A room 4m x 5m x 6m is heated by a baseboard resistance heater, and is to raise the temperature of the room from 7°C to 23°C within 15 minutes. Assuming no heat is lost from the room and that the atmospheric pressure is 100 kPa, determine the power necessary for the heater to accomplish this. Assume constant specific heats at the room temperature.

\[
\frac{E_{\text{in}} - E_{\text{out}}}{\text{Net energy transfer by heat, work, and mass}} = \frac{\Delta E_{\text{system}}}{\text{Change in internal, kinetic, potential, etc. energies}}
\]

\[W_{e,\text{in}} = \Delta U \cong mc_{p,avg}(T_2 - T_1) \quad \text{(since } Q = KE = PE = 0)\]

or,

\[\dot{W}_{e,\text{in}} \Delta t = mc_{p,avg}(T_2 - T_1)\]

The mass of air is

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

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

Substituting, the power rating of the heater becomes

\[\dot{W}_{e,\text{in}} = \frac{(149.3 \text{ kg})(0.718 \text{ kJ/kg} \cdot ^\circ \text{C})(23 - 7)^\circ \text{C}}{15 \times 60 \text{ s}} = 1.91 \text{ kW}\]
Problem 5.68E
A 3-ft³ adiabatic rigid container is divided into two equal volumes by a thin membrane. Initially, one of the chambers is filled with air at 100 psia and 100°F, while the other chamber is evacuated. Determine a) the internal energy change of the air when the membrane is ruptured, and b) the final air pressure in the container.

\[
\frac{E_{in} - E_{out}}{\text{Net energy transfer by heat, work, and mass}} = \frac{\Delta E_{system}}{\text{Change in internal, kinetic, potential, etc. energies}}
\]

\[
0 = \Delta U = mc_\nu (T_2 - T_1)
\]

Since the internal energy does not change, the temperature of the air will also not change. Applying the ideal gas equation gives

\[
P_1V_1 = P_2V_2 \quad \rightarrow \quad P_2 = P_1 \frac{V_1}{V_2} = P_1 \frac{\frac{V_2}{2}}{\frac{V_2}{2}} = \frac{P_1}{2} = \frac{100\text{ psia}}{2} = 50\text{ psia}
\]
Problem 5.73
A piston-cylinder device contains argon gas as a system undergoes an isothermal process from 200 kPa and 100°C to 50 kPa. During the process, 1500 kJ of heat is transferred to the system. Determine the mass of the system and the amount of work produced.

\[
\frac{E_{\text{in}} - E_{\text{out}}}{\text{Net energy transfer by heat, work, and mass}} = \frac{\Delta E_{\text{system}}}{\text{Change in internal, kinetic, potential, etc. energies}}
\]

\[
Q_{\text{in}} - W_{b,\text{out}} = \Delta U = mc_v (T_2 - T_1)
\]

\[
Q_{\text{in}} - W_{b,\text{out}} = 0 \quad \text{(since } T_1 = T_2) \]

\[
Q_{\text{in}} = W_{b,\text{out}}
\]

Thus,

\[
W_{b,\text{out}} = Q_{\text{in}} = 1500 \text{ kJ}
\]

Using the boundary work relation for the isothermal process of an ideal gas gives

\[
W_{b,\text{out}} = m \int_1^2 P \, dv = mRT \int_1^2 \frac{dv}{\nu} = mRT \ln \frac{\nu_2}{\nu_1} = mRT \ln \frac{P_1}{P_2}
\]

Solving for the mass of the system,

\[
m = \frac{W_{b,\text{out}}}{RT \ln \frac{P_1}{P_2}} = \frac{1500 \text{ kJ}}{0.2081 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K}(373 \text{ K}) \ln \frac{200 \text{ kPa}}{50 \text{ kPa}}} = 13.94 \text{ kg}
\]