Solution to Assignment No: 3  
Fall 2000  
Instructor: J. Murthy

4.11

Solution:

\( a) \ T_{r1} = \frac{T}{T_c} = \frac{573.15}{425.2} = 1.35; \ P_{r1} = \frac{P}{P_c} = \frac{100}{3800} = 0.026 \)

From the generalized chart in figure D.1 \( Z_1 = 0.99 \)

\( T_{r2} = \frac{T}{T_c} = \frac{573.15}{425.2} = 1.35; \ P_{r2} = \frac{P}{P_c} = \frac{300}{3800} = 0.079 \)

From the generalized chart in figure D.1 \( Z_2 = 0.98 \)

Ideal gas model is adequate for both states.

\( b) \) Ideal gas \( T = \text{constant} \Rightarrow PV = mRT = \text{constant} \)

\[ W = \int P \, dV = P_1 V_1 \ln \frac{P_1}{P_2} = 100 \times 0.02 \times \ln \frac{100}{300} = -2.2 \text{ kJ} \]

4.14

Solution:

By knowing the process and the states 1 and 2 we can find the relation between the pressure and the volume so the work integral can be performed.

Process: \( PV = C \Rightarrow V_2 = P_1 V_1 / P_2 = 1000 \times 0.1 / 100 = 1 \text{ m}^3 \)

\[ W_{12} = \int P \, dV = \int CV^{-1} \, dV = C \ln(V_2 / V_1) \]

\[ W_{12} = P_1 V_1 \ln \frac{V_2}{V_1} = 1000 \times 0.1 \ln (1/0.1) \]

\[ = 230.3 \text{ kJ} \]

4.19

Solution:

Process: \( P \propto D^2, \) with \( V \propto D^3 \) this implies \( P \propto D^2 \propto V^{2/3} \) so

\( PV^{-2/3} = \text{constant}, \) which is a polytropic process, \( n = -2/3 \)

From table B.2.1: \( V_1 = mV_1 = 2(0.001566 + 0.6 \times 0.28783) = 0.3485 \text{ m}^3 \)

\[ V_2 = V_1 \left( \frac{P_2}{P_1} \right)^{3/2} = 0.3485 \left( \frac{600}{429.3} \right)^{3/2} = 0.5758 \text{ m}^3 \]

\[ W_{12} = \int P \, dV = \frac{P_2 V_2 - P_1 V_1}{1 - n} \quad (\text{Equation 4.4}) \]

\[ = \frac{600 \times 0.5758 - 429.3 \times 0.3485}{1 - (-2/3)} = 117.5 \text{ kJ} \]
4.24

Solution:
(a) State to reach lift pressure of
\[ P = 400 \text{ kPa}, \quad v = V/m = 0.1 \text{ m}^3/\text{kg} \]
Table B.1.2: \( v_f < v < v_g = 0.4625 \)
\[ \Rightarrow T = T_{\text{sat}} = 143.63^\circ C \]
(b) State 2 is saturated vapor at 400 kPa since state 1 is two-phase.
\[ v_2 = v_g = 0.4625 \text{ m}^3/\text{kg}, \quad V_2 = m v_2 = 0.4625 \text{ m}^3, \]
Pressure is constant as volume increase beyond initial volume.
\[ W_2 = \int P \, dV = P (V_2 - V_1) = mP (v_2 - v_1) = 400 (0.4625 - 0.1) = 145 \text{ kJ} \]

4.48

Solution:
Steady conduction through the bottom of the steel pot. Assume the inside surface is at the liquid water temperature.
\[ \dot{Q} = k A \frac{\Delta T}{\Delta x} \Rightarrow \Delta T = \dot{Q} \Delta x / kA \]
\[ \Delta T = 250 \times 0.005/(50 \times \frac{\pi}{4} \times 0.22)^2 = 0.796 \]
\[ T = 15 + 0.796 \approx 15.8^\circ C \]

4.50

Solution:
The heat transfer from the inside must match the loss on the outer surface to give a steady state (frost free) outside surface temperature.
\[ \dot{Q}_{\text{conv}} = h A \Delta T = 250 \times 0.5 \times (2\cdot(-15)) \]
\[ = 250 \times 0.5 \times 17 = 2125 \text{ W} \]
This is a substantial amount of power.

4.55

Solution:
\[ \frac{\dot{Q}}{A} = \varepsilon \sigma AT^4, \quad \sigma = 5.67 \times 10^{-8} \]
a) \[ \dot{Q}/A = 0.7 \times 5.67 \times 10^{-8} \times (273.15 + 30)^4 = 335 \text{ W/m}^2 \]
b) \[ \dot{Q}/A = 0.9 \times 5.67 \times 10^{-8} \times 288.15^4 = 352 \text{ W/m}^2 \]