ME 24-221
Thermodynamics I

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 = constant $\Rightarrow$ PV = mRT = constant

$$W = \int PdV = P_1V_1 \ln\frac{P_1}{P_2} = 100 \times 0.02 \times \ln\frac{100}{300} = \mathbf{-2.2\ kJ}$$

4.14

Solution:

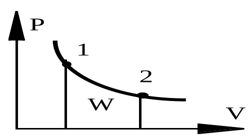
By knowing the process and the states 1 and 2 we can find the relation between the pressure and the volume so the work integral can be performed.

Process: PV = C $\Rightarrow$ $V_2 = P_1V_1/P_2 = 1000 \times 0.1/100 = 1\ m^3$

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

$$W_{12} = P_1V_1 \ln\frac{V_2}{V_1} = 1000 \times 0.1 \ln(1/0.1)$$

$$= \mathbf{230.3\ kJ}$$



4.19

Solution:

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

$PV^{-2/3}$ = constant, which is a polytropic process, n = -2/3

From table B.2.1: $V_1 = mv_1 = 2(0.001566 + 0.6 \times 0.28783) = 0.3485\ m^3$

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

$$W_{12} = \int_1^2 PdV = \frac{P_2V_2 - P_1V_1}{1 - n} \qquad \text{(Equation 4.4)}$$

$$= \frac{600 \times 0.5758 - 429.3 \times 0.3485}{1 - (-2/3)} = \mathbf{117.5\ kJ}$$

4.24

Solution:

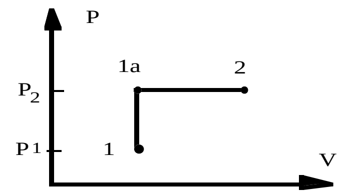
(a) State to reach lift pressure of

$P = 400$ kPa, $v = V/m = 0.1\ m^3/kg$

Table B.1.2: $v_f < v < v_g = 0.4625$

$\Rightarrow \quad T = T_{sat} = \mathbf{143.63°C}$

(b) State 2 is saturated vapor at 400 kPa since state a is two-phase.



$v_2 = v_g = 0.4625\ m^3/kg$, $V_2 = m\, v_2 = 0.4625\ m^3$,

Pressure is constant as volume increase beyond initial volume.

${}_1W_2 = \int P\, dV = P\,(V_2 - V_1) = mP\,(v_2 - v_1) = 400\,(0.4625 - 0.1) = \mathbf{145\ kJ}$

4.48

Solution :

Steady conduction through the bottom of the steel pot. Assume the inside surface is at the liquid water temperature.

$$\dot{Q} = k\ A\ \frac{\Delta T}{\Delta x} \;\Rightarrow\; \Delta T = \dot{Q}\ \Delta x / kA$$

$$\Delta T = 250 \times 0.005/(50 \times \frac{\pi}{4} \times 0.2^2) = 0.796$$

$$T = 15 + 0.796 \cong \mathbf{15.8\ °C}$$

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.

$$\dot{Q}_{conv} = h\ A\ \Delta T = 250 \times 0.5 \times (2-(-15))$$

$$= 250 \times 0.5 \times 17 = \mathbf{2125\ W}$$

This is a substantial amount of power.

4.55

Solution :

$$\dot{Q}/A = \varepsilon\sigma A T^4, \quad \sigma = 5.67 \times 10^{-8}$$

a) $\dot{Q}/A = 0.7 \times 5.67 \times 10^{-8} \times (273.15 + 30)^4 = \mathbf{335\ W/m^2}$

b) $\dot{Q}/A = 0.9 \times 5.67 \times 10^{-8} \times 288.15^4 = \mathbf{352\ W/m^2}$