Homework 3 Solutions

1. State 1 (7 points - 1 each for a-g)

a) \[ n = \frac{0.001 \text{ m}^3}{\text{kg}} \]
   \[ n_1 = \frac{m}{v_1} = \frac{0.05 \text{ m}^3}{0.001 \text{ m}^3/\text{kg}} = \]  50

b) \[ v_2 = \frac{0.79645 \text{ m}^3}{\text{kg}} \]
   \[ v_2 = 50 \text{ kg} \times 0.79645 \text{ m}^3/\text{kg} = 39.8 \text{ m}^3 \]

\[ h_1 \approx h_f @ 1^\circ \text{C} = 42.022 \text{ kJ/kg} \]
\[ h_2 = 2967.9 \text{ kJ/kg} \]
\[ \Delta H = m(h_2 - h_1) = 50 \text{ kg} \times (2967.9 - 42.022) \text{ kJ} = 146294 \text{ kJ} \]

\[ \Delta H = \frac{146294 \text{ kJ}}{10^3 \text{ MJ}} = 146 \text{ MJ} \]

\[ d) \ x_3 = 0.5 \]

\[ v_3 = 0.5 (v_{fg}) + v_f @ 250^\circ \text{C} \]
\[ = 0.5 (0.050085) + 0.001252 \text{ m}^3/\text{kg} \]
\[ = 0.02567 \text{ m}^3/\text{kg} \]
\[ v_3 = 50 \text{ kg} \times 0.02567 \text{ m}^3/\text{kg} = 1.28 \text{ m}^3 \]

\[ e) \ P_3 = P_{sat} @ 250^\circ = \frac{3976.2 \text{ kPa}}{4 \text{ MPa}} \]

\[ f) \ h_3 = 0.5 (h_{fg}) + h_f @ 250^\circ = 0.5 (1715.3) + 1085.7 \text{ kJ/kg} \]
\[ h_3 = 1943.4 \text{ kJ/kg} \]
1. \( \Delta H = m \left( h_2 - h_1 \right) = 50 \text{ kg} \left( 1943.4 - 42.022 \right) \text{kJ/kg} \)

\[ \Delta H = 95,066 \text{ kJ} \] or \( \approx 95 \text{ MJ} \)

(see graph)

2. Compressed liquid water @ 100°C, 15 MPa

Find \( v, u, h \) from

\begin{align*}
  v &= v_f @ 100^\circ C = 0.001043 \text{ m}^3/\text{kg} \\
u &= u_f @ 100^\circ C = 419.06 \text{ kJ/kg} \\
h &= h_f @ 100^\circ C = 419.07 \text{ kJ/kg}
\end{align*}

(from Table A.7)

\begin{align*}
v &= 0.0010361 \text{ m}^3/\text{kg} \quad (< 1\% \text{ difference}) \\
u &= 415.85 \text{ kJ/kg} \quad (1\% \text{ difference}) \\
h &= 430.39 \text{ kJ/kg} \quad (3\% \text{ difference})
\end{align*}

3. Piston-cylinder with 0.8 kg steam @ 300°C

and 1 MPa (superheated)

is cooled @ 300°C until \( x = 0.25 \) \( \quad \text{(1)} \)

\( T_2 = T_{sat} @ 1 \text{ MPa} = \left[ 179.9^\circ C \right] \) \( \text{(4.5)} \)

\[ v_2 = x \cdot v_{fg} + v_f @ 1 \text{ MPa} \]

\[ v_2 = 0.25 \left( 0.19436 - 0.001127 \right) + 0.001127 \text{ m}^3/\text{kg} \]

\[ v_2 = 0.04944 \text{ m}^3/\text{kg} \]

\[ \frac{V_2 = 0.8 \text{ kg} \left( 0.04944 \text{ m}^3/\text{kg} \right)}{\text{kg}} = 0.04 \text{ m}^3 \]

(see graph)

\[ V = 0.8 \text{ kg} \left( 0.25 \text{ m}^3/\text{kg} \right) = 0.2064 \text{ m}^3 \]
4. Rigid tank with R-134a (isochoric process)
   \( V = \rho m = 0.01450 \times 1 \text{ kg} = 0.01450 \text{ m}^3 \)
   \( T_1 = -40^\circ C \) \( v_f < v < v_g @ -40^\circ C \)
   \( T_2 = 90^\circ C \)

   a) \( P_1 = P_{sat} @ 40^\circ C = 51.25 \text{ kPa} \)
   b) \( P_2 = 200 \text{ kPa} \)

   \( v > v_g @ 200 \text{ kPa} \Rightarrow \text{ superheated R-134a from A-13} \)

5. Ideal gas (O2)
   \( P_g = 500 \text{ kPa} \), \( V_1 = 1.3 \text{ m}^3 \)
   \( T_1 = 24^\circ C \), \( P_{atm} = 97 \text{ kPa} \)

   Find \( M \)

   \[ PV = mRT \]

   \[ R = 0.2598 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} \]

   \[ m = \frac{(500+97) \text{ kPa} \times 1.3 \text{ m}^3}{0.2598 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} \times (273+24) \text{ K}} = 10 \text{ kg} \]

6. for \( T = 25^\circ C = 298 \text{ K} \)
   \( P_g = 210 \text{ kPa} \), \( P_{atm} = 100 \text{ kPa} \), \( P = 310 \text{ kPa} \)
   \( V = 0.025 \text{ m}^3 \)
   @\( T = 50^\circ C = 323 \text{ K} \), find \( m_2 - m_1 \), such that

   \( P = 310 \text{ kPa} \), assume \( V_2 = V_1 \)
1. 
\[ P_2 = \frac{T_2}{P_1 / T_1} = 323 \frac{310 \text{kPa}}{298 \text{K}} = 336 \text{kPa} \]
\[ M_1 = \frac{310 (0.025) \text{KN-m}}{0.287 \text{KJ (298K)}} = 0.0906 \text{ kg} \]
\[ P_1 V_1 = M_1 RT_1 \]
\[ P_1 V_1 = M_2 RT_2 \]
\[ M_1 T_1 = M_2 T_2 \]
\[ \frac{M_2}{M_1} = \frac{T_1}{T_2} \]
\[ M_2 = 0.0906 \left(\frac{298}{323}\right) \]
\[ M_2 = 0.084 \text{ kg} \]
\[ M_1 - M_2 = 0.0906 - 0.084 = 0.007 \text{ kg} \]

2. 
\[ A_r, 0.2 \text{ kg, piston-cylinder, } V = 0.05 \text{ m}^3 \]
\[ P_1 = 400 \text{kPa, isothermal expansion} \]
\[ V_2 = 2V_1 = 0.1 \text{ m}^3 \]
\[ \text{find } P_2 \text{ for ideal gas, isothermal expansion, closed system, } \]
\[ P_1 V_1 = P_2 V_2 \]
\[ P_2 = P_1 \frac{V_1}{V_2} = 400 \text{kPa} \left(\frac{0.5}{0.5}\right) = 200 \text{kPa} \]

3. 
\[ \text{rigid tank, ideal gas @ 300 \text{kPa, 600K} } \]
\[ M_2 = 0.5 m_1, P_2 = 100 \text{kPa} \]
4. 
\[ \text{find } T_2 \quad P_1 V_1 = M_1 RT_1 \quad P_2 V_1 = M_2 RT_2 \]
8. a) \[ \frac{m_1 T_1}{P_1} = \frac{m_2 T_2}{P_2} \]
\[ M_1 = 2m_2 \]

\[ 2 \frac{T_1}{P_1} = \frac{T_2}{P_2} \]

\[ T_2 = 2 \left( \frac{P_2}{P_1} \right) T_1 = 2 \left( \frac{100}{300} \right) 600k \]

\[ T_2 = \left[ \frac{400k}{400k} \right] \]

b) now \( M_1 = M_2 \)

1. \[ T_2 = 400k \]

\[ \frac{T_1}{P_1} = \frac{T_2}{P_2} \]

\[ P_2 = \frac{T_2}{T_1} (P_1) \]

\[ P_2 = 300kPa \left( \frac{400}{600} \right) = 200 \text{kPa} \]

9. R-134a in piston-cylinder (not isobaric process)

\[ m = 25 \text{kg}, \; P_1 = 320 \text{kPa}, \; v_1 = 0.0834 \text{m}^3/\text{kg} \]

\[ v_1 < v_g @ 320 \text{kPa}, \; \text{superheated} \]

a) \[ T_1 = \left[ 70^\circ \text{C} \right] \text{(A-13)} \]

b) \[ v_2 = v_1 = v_g \] \[ \Rightarrow \]
\[ P_2 = 240 \text{kPa} \]

\[ T_2 = -5.38^\circ \text{C} \]
c) Isobaric condensation \( T_3 = T_2 = -5.38^\circ C \)

\[
V_3 = \frac{m V_3}{m} = \frac{m v_f \rho @ 240kPa}{kg}
\]

\[
V_3 = 25kg \cdot (0.000762 \frac{m^3}{kg}) = 0.02 m^3
\]

d) \[
\Delta H = m (h_3 - h_1) = 25kg \cdot (44.66 - 313.48) \frac{kJ}{kg} = 6,720 kJ
\]

\[
\Delta H = \frac{6,720 kJ}{kg}
\]

e) Work = \int PdV = \int PdV

Since \( \int PdV = 0 \) (constant \( V \))

\[
\text{for } 2 \rightarrow 3, \text{ Work at } P = \text{ constant } \]

\[
W = P \int dV = P (V_3 - V_2)
\]

\[
W = P \cdot m (V_3 - V_2) = 240kPa \cdot 25kg \cdot (0.000762 - 0.00834) m^3
\]

\[
W = \boxed{49.6 kJ}\text{ Work done on R-134a}
\]
AREN 2110  
Spring 2011  

Homework #3: Due Friday, Feb. 4, 6 PM  

1. A piston-cylinder device initially contains 50L of liquid water at 10 °C and 300 kPa. Heat is added to the water at constant pressure until the temperature reaches 250 °C. Determine the following:  
   a) the mass of the water  
   b) the volume after heating in m³  
   c) the enthalpy change after heating in kJ  

Now the water is compressed in an isothermal process until half the mass is in the liquid form.  
   d) What is the final volume?  
   e) What is the final pressure?  
   f) What is the enthalpy change in the water for the 2-step process?  
   g) Show the two processes on the T-v diagram  

![Water: Liquid-vapor phases](chart)  

2. Determine the specific volume, internal energy and enthalpy of compressed liquid water at 100 °C and 15 MPa using the saturated liquid approximation. Compare these values to the ones obtained from the compressed liquid tables.  

3. A piston-cylinder device contains 0.8 kg of steam at 300°C and 1 MPa. Steam is cooled at constant pressure until on 75% of its mass condenses. Show the process on a T-v diagram, find the final temperature and determine the volume change.
4. A rigid-wall tank with a volume of 0.1450 m$^3$/kg contains one kg of R-134a at a temperature of -40 °C (233K). The container is heated until the pressure of the R-134a is 200 kPa.

   a) What is the initial pressure?
   b) What is the final temperature of the R-134a?
   c) Draw the process on the T-v diagram

5. The pressure gage on a 1.3 m$^3$ oxygen tank reads 500 kPa. Determine the amount of oxygen in the tank if the temperature is 24 C and atmospheric pressure is 97 kPa.
calculate the work done between states 1 and 3. Is the work positive or negative?

f) Graph the process sequence on the P-V diagram (below)