1. Use the P-V diagram below to answer the following questions

1a) The Net Work for the cyclic process is:
   a) Zero
   b) Positive
   c) Negative
   d) Cannot tell from the diagram

1b) The processes from states 1 to 2 and 3 to 4 are:
   a) Isothermal
   b) Isobaric
   c) Isochoric
   d) Isometric

1c) The Net Heat Transfer for the cyclic process is:
   a) Zero
   b) Positive
   c) Negative
   d) Cannot tell from the diagram
2. **State 1:** Ten (10) kg of saturated liquid water at 100 °C and 0.10133 MPa with a specific volume of 0.001044 m³/kg is contained in a tank connected to a second empty tank through a pipe with a closed valve. The valve is opened and the water expands isothermally into the second tank until equilibrium is reached.

**State 2:** 10 kg water at 100 °C and 0.01 MPa.

![Diagram of tank system](image)

2a) Draw the process on the P-v diagram below, showing process directions:

![P-v diagram for water](image)

2b) The total volume of the two tanks is (justify your answer):

- a. 172 m³
- b. 16.7 m³
- c. 146.7 m³
- d. Cannot be determined from the information given
3. A one-liter volume of liquid water at 25 °C and 1 atmosphere pressure is cooled to 0 °C and eventually frozen completely at constant pressure. The final temperature of the ice is 0 °C. Calculate the total change in enthalpy of the water.

4. A piston/cylinder system has 2 kg of R-134a refrigerant at $T=40^\circ\text{C}$ and $P=800$ kPa. The refrigerant is cooled to $T=20^\circ\text{C}$ at constant pressure. (The R-134a tables are A-8 to A-10, pp 857-860)

4a) What is the saturation temperature for R-134a in this system?

4b) Draw the process on the $T$-$v$ diagram below.
5. A piston/cylinder starts at pressure $P_1$ and volume $V_1$ and undergoes the following cycle:
   1→2 Isobaric expansion to triple the original volume
   2→3 Compression to twice the original volume according to the $P-V$ relation
   \[ P = 4P_1 - \frac{P_1}{V_1} V \]
   3→4 Isobaric compression to the original volume
   4→1 Isochoric heat removal returning the system to its original pressure

a) Draw a $P-V$ diagram for the cycle labeling all points and indicating direction

b) Compute the net work of the cycle

6. Twenty-five (25) kg of helium gas at a temperature of 300 K and pressure of 20 kPa is compressed until the pressure doubles. During the compression the gas properties follow the expression:

\[ PV^2 = \text{constant} \]

a. What is the final temperature of the helium?
b. What is the work done during the compression?

7. The temperature of two kilograms of water contained in an 0.20-m³ rigid tank is 200 °C. Determine:

a. the pressure in the system

b. the specific enthalpy of the system

c. the mass of the vapor phase

d. the volume of the vapor phase

8. Fill in the property table below for water in the specified equilibrium states:

<table>
<thead>
<tr>
<th>T(°C)</th>
<th>P (kPa)</th>
<th>h (kJ/kg)</th>
<th>v (m³/kg)</th>
<th>x</th>
<th>phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) 133.55</td>
<td>300</td>
<td>1643.4</td>
<td>0.3034</td>
<td>0.5</td>
<td>liquid-vapor mix</td>
</tr>
<tr>
<td>b) 179.91</td>
<td>1000</td>
<td>762.81</td>
<td>0.00127</td>
<td>0</td>
<td>saturated liquid</td>
</tr>
<tr>
<td>c) 80</td>
<td>125</td>
<td>334.91</td>
<td>0.001029</td>
<td>na</td>
<td>compressed liquid</td>
</tr>
<tr>
<td>d) 400</td>
<td>600</td>
<td>3270.3</td>
<td>0.5137</td>
<td>na</td>
<td>superheated vapor</td>
</tr>
</tbody>
</table>

a) mixture (0<x<1), T=Tsat
   \[ h = h_f + x \cdot h_{fg} \bigg|_{133.55} \]
   \[ h = 561.47 + 0.5(2163.8) = 1643.4 \text{ kJ/kg} \]
   \[ v = v_f + x \cdot v_{fg} = 0.001073 + 0.5(0.0058 - 0.001073) = 0.3034 \text{ m³/kg} \]

b) Table A-5
   \[ \Rightarrow \text{cond, } h \approx h_f \bigg|_{80} = v \cdot v_f \bigg|_{80} \]

c) T<Tsat (125kPa)
   \[ \Rightarrow \text{compressed liquid, A-6} \]

d) h>h_{fg} \bigg|_{133°C}
   \[ \Rightarrow \text{superheated vapor, } A-6 \]
2. State 1: \(T = T_{sat} \mid 101.325 \text{kPa} \Rightarrow \text{saturated liquid}\)

State 2: 10 kPa \((0.01 \text{MPa})\), \(T > T_{sat} \Rightarrow \text{superheated vapor}\) Table A.6

\[v_a = 17.198 \text{ m}^3/\text{kg}\]

\[V = m v_a = 10 \text{ kg} \left(17.2 \frac{\text{m}^3}{\text{kg}}\right) = 172 \text{ m}^3\]

3. \(h_1 = h_f \mid 125^\circ C = 104.89 \text{ kJ/kg}\)

\[h_a = h_f \mid 0^\circ C = 0 \quad M = \frac{V}{v_a} = \frac{0.001 \text{ m}^3}{0.001003 \frac{\text{m}^3}{\text{kg}}} = 0.997 \text{ kg}\]

\[h_i = 333.7 \text{ kJ/kg}\]

\[\Delta H = m \left[ \frac{h_a}{v_a} - h_1 \right] + h_i = 0.997 \left[ 104.89 + 333.7 \right] = 437.3 \text{ kJ}\]

\[\Delta H = M C (T_2 - T_1) + m h_i = 0.997 \left[ 4.12 \frac{\text{kJ}}{\text{kg} \cdot ^\circ C} (25) + 333.7 \right] = 437.4 \text{ kJ}\]
4.  
   1. \( M = 2k_a \) \( R \) \( \beta \)  
   \( T = 40^\circ C \), \( P = 800 \text{ kPa} \) (superheated vapor)

2. \( T = 20^\circ C \), \( P = 800 \text{ kPa} \) (compressible constant \( P \) process)
   
   a) \( 31.33^\circ C = T_{sat} \left|_{800 \text{ kPa}} \right. \)

   b) \( v_1 = 0.02691 \text{ m}^3/\text{kg} \)

   \[ \frac{v_2}{v_f} = \left. 0.0008157 \text{ m}^3/\text{kg} \right|_{20^\circ C} \]

5. a) \( P = 4P_1 - \frac{P_1}{V_1} V \), \( V = 2V_1 \)

   \[ P = 4P_1 - 2P_1 = 2P_1 \]

   b) \( W_{net} = \text{Area trapezoid} \)

   \[ = \left( (3V_1 - V_1) + \frac{V_1}{2} \right) P_1 \]

   \[ = \frac{-3}{2} V_1 P_1 \] (work done on system)
He, 25 kg  \( T_1 = 300 \text{k} \)  \( P_1 = 20 \text{kPa} \)

\[ P_2 = 40 \text{kPa} \]

\[ PV^2 = c \quad n = 2 \]

\[ P_1 V_1^2 = P_2 V_2^2 \]

\[ \frac{P_2}{P_1} = 2 = \left( \frac{V_1}{V_2} \right)^2 \quad \frac{V_2}{V_1} = \sqrt[2]{\frac{1}{2}} \]

He is ideal gas
Closed system, mass = constant

\[ \frac{P_2 V_2}{P_1 V_1} = \frac{T_2}{T_1} \]

\[ T_2 = T_1 \left(2\right) \left(\frac{1}{1.12}\right) \]

\[ T_2 = 300 \left(\frac{1}{1.12}\right) = 424.3 \text{k} \]

\[ W_b = mR(T_2 - T_1) \quad \text{from } W_b = (P_2 V_2 - P_1 V_1) \]

\[ = 25 \text{kg} \times 2.0769 \text{kJ/(kgK)} \left(424.3 - 300\right) \]

\[ = \frac{25 \times 2.0769 \times (124.3)}{1 - 2} \]

\[ \text{for all gases} \]

\[ \text{for ideal not Isoth} \]

\[ P_2 V_2 - P_1 V_1 = mR(T_2 - T_1) \]
6. \( W_b = -6.452 \text{ kJ} \)

7. A kg water in 0.2 m^3 tank \( T = 200^\circ \text{C} \)

a) \( P = ? \)

\[
V = \frac{0.2}{a} = 0.1 \text{ m}^3 \text{ kg}^{-1} \\
V_f < 0.1 < V_g \Rightarrow \text{mixture} \\
\frac{1}{200^\circ \text{C}} \text{ P} = P_{\text{sat}} = 1.5538 \text{ MPa} \]

b) \( h = h_f + x h_{fg} \)

need \( x \)? \( x = \frac{V - V_f}{V_{fg}} \text{ at } 200^\circ \text{C} \)

\[
x = 0.1 - 0.002157 = 0.783 \\
x = 0.12736 - 0.002157 \\
\]

\( h = 852.45 + 0.783 (1940.7) \)

\( h = 2372.4 \text{ kJ kg}^{-1} \)

c) \( m_g = x m_g = 0.783 (2) = 1.566 \text{ kg} \)

d) \( V_g = m_g v_g = 1.566 \text{ kg} (0.12736) \)

\( = 0.1994 \text{ m}^3 (99.7\% \text{ of } V_t) \)