Answer all questions. Test is open book and notes. Sign honor code statement below.

I have neither given nor received unauthorized assistance during this examination.

Signed ________________________________

1. (6 points @ 2 points per question) Multiple choice Circle THE BEST answer (only one answer per question)

   A. Saturated water vapor condenses to saturated liquid at a constant temperature. The boundary work in kJ can always be determined by:
   a. \( P_1 V_1 \ln \left( \frac{V_2}{V_1} \right) \)
   b. \( m*(h_2 - h_1) \)
   c. \( P*(V_2 - V_1) \)
   d. \( (P_2 V_2 - P_1 V_1)/(1-n) \)
   e. \( m*c_p*(T_2 - T_1) \)

   B. Which of the following IS NOT an example of a PROCESS PATH
   a. isothermal
   b. adiabatic
   c. isochoric
   d. quasi-equilibrium
   e. condensation

   C. For an ideal gas, the specific heats, \( c_v \) and \( c_p \), are related by:
   a. \( c_v \approx c_p \)
   b. \( c_v = c_p + R \)
   c. \( c_p = c_v + R \)
   d. \( c_p = c_v + dh/dT \)
   e. \( c_p = c_v + du/dT \)

2. (8 points @ 1 point per unknown)

<table>
<thead>
<tr>
<th>Substance</th>
<th>P (kPa)</th>
<th>T (°C)</th>
<th>( u ) (kJ/kg)</th>
<th>( x^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td>H_2O</td>
<td>1000</td>
<td>180</td>
<td>1490</td>
<td>0.4</td>
</tr>
<tr>
<td>H_2O</td>
<td>1000</td>
<td>100</td>
<td>419</td>
<td>na</td>
</tr>
<tr>
<td>H_2O</td>
<td>1000</td>
<td>1000</td>
<td>4053</td>
<td>na</td>
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<tr>
<td>H_2O</td>
<td>1000</td>
<td>180</td>
<td>1000</td>
<td>0.13</td>
</tr>
</tbody>
</table>

\[ u = 0.4(1821.4) + 761.39 = 1490 \text{ kJ/kg} \]

   Complication: \( u = u_f + cP_{100°C} = 419 \)  

   Superheat: \( u = 4052.7 \)  

   \( u_f < u < u_g \) at 1MPa: \( x = \frac{1000 - 761.39}{1821.4} = 0.13 \)
Write the appropriate number for each of the processes or states on the P-v graph above next to the correct process description. Each number only fits one description.

Isothermal process, T = 311 °C  

Isothermal process, P = 10 MPa  

Isochoric Process, P₁ = 10 MPa  

Isobaric process, T = 264 °C  

Isobaric process, T = 10 MPa  

Supercritical Steam, T = 500 °C  

Saturated mixture, x > 0.5  

Saturated mixture, x < 0.5  

Cycle, Wₜ > 0  

Cycle, Wₜ < 0  

Cycle, Wₜ = 0
4. (8 points – 2 points per answer). A piston-cylinder device is to be designed to produce work from the expansion of air in an isobaric process. The device will be designed for quadrupling the volume of air in the cylinder with an initial temperature of 27 °C. The pressure is 100 kPa.

a) Calculate the final temperature of the air.

\[
\frac{T_1}{V_1} = \frac{T_2}{V_2} \quad V_2 = 4V_1 \quad T_1 = 27 + 273 = 300 \text{k} \]

\[
T_2 = T_1 \cdot \frac{V_2}{V_1} = 300 \text{k} \cdot 4 = 1200 \text{k} \]

b) The required work to be produced is 600 kJ. What are the initial and final volumes of the air?

\[
W_b = P \cdot (V_2 - V_1) = 600 \text{kJ}
\]

\[
600 \text{kJ} = 100 \text{kPa} \cdot (4V_1 - V_1) \]

\[
V_1 = \frac{600 \text{kJ}}{100 \text{kJ/m}^3 \cdot 3} = \frac{1}{2} \text{m}^3
\]

\[
V_2 = 4 \cdot (2 \text{m}^3) = 8 \text{m}^3
\]

c) What is the mass of air in the cylinder?

\[
M = \frac{P \cdot V_1}{RT_1} = \frac{100 \text{kPa} \cdot 2 \text{m}^3}{0.287 \text{kJ/kg} \cdot 300 \text{k}} = \frac{2.3 \text{kg}}{}
\]

d) If the process were to be carried out isothermally with the same initial conditions as those above, what is the work done by the system?

\[
W_b = P \cdot V_1 \cdot ln \left( \frac{V_2}{V_1} \right) = \frac{100 \text{kPa} \cdot 2 \text{m}^3 \ln (4)}{277 \text{kJ}}\]

\[
W_b = \frac{2.3 \text{kg} \cdot 0.287 \text{kJ/kg} \cdot 300 \text{k} \ln (4)}{277 \text{kJ}} = 277 \text{kJ}\]
Useful values.

Ideal gas: air

<table>
<thead>
<tr>
<th>R</th>
<th>C_p (kJ/kg-K)</th>
<th>C_v (kg/kmol)</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.287</td>
<td>1.005</td>
<td>0.718</td>
<td>29</td>
</tr>
</tbody>
</table>

Water

Saturated liquid vapor and superheated steam properties

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>P (kPa)</th>
<th>u_f (kJ/kg)</th>
<th>u_fg (kJ/kg)</th>
<th>u_g (kJ/kg)</th>
<th>u</th>
</tr>
</thead>
<tbody>
<tr>
<td>179</td>
<td>1000</td>
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<td>1821.4</td>
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<tr>
<td>100</td>
<td>101</td>
<td>419.06</td>
<td>2087.0</td>
<td>2506.0</td>
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<tr>
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<td>1148.1</td>
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<td>10000</td>
<td>1393.3</td>
<td>1151.8</td>
<td>2545.2</td>
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<tr>
<td>325</td>
<td>10000</td>
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</table>

SCORE

1. ________(6)

2. ________(8)

3. ________(8)

4. ________(8)

Σ. __________(30)