ME 200 Thermodynamics 1
Fall 2018 – Final Exam

Circle your instructor’s last name

<table>
<thead>
<tr>
<th>Division 1 (7:30): Naik</th>
<th>Division 2 (9:30): Choi</th>
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</thead>
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<tr>
<td>Division 3 (1:30): Wassgren</td>
<td>Division 4 (8:30): Holloway</td>
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<td>Division 6 (11:30): Sojka</td>
<td>Division 7 (2:30): Vuppuluri</td>
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<td>Division 8 (12:30): Buckius</td>
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INSTRUCTIONS

- **Do not remove staples from any page.** If you use extra paper, attach it at the end of the exam with a paper clip and indicate above how many extra sheets were attached.
- **Do not write on the back of any page** because it will not be scanned so will not be graded.
- **This is a closed book and closed notes exam.** Equation sheets and all needed tables are provided.
- Significant credit for each problem is given if you identify your system and its boundary, draw the relevant energy flows on a diagram, i.e., Energy Flow Diagram (EFD), start your analysis with the basic equations, list all relevant assumptions, have appropriate units, and use three significant figures for final answers. There is no need to re-write the given and find.
- Do not hesitate to ask if you do not comprehend a problem statement. For your own benefit, please write clearly and legibly. **You must show your work to receive credit for your answers.**

IMPORTANT NOTE

The use of PDAs, Blackberry-type devices, cell phones, laptop computers, smart watches or any other sources of communication (wireless or otherwise) is strictly prohibited during examinations. Doing so is cheating. If you bring a smart watch, cell phone, or other communication device to the examination, **it must be turned off** prior to the start of the exam, **placed in your backpack, and the backpack must be stored below your seat.** It shall be **reactivated only after you leave the examination room for the final time.** Otherwise it is a form of cheating and will be treated as such.

SECOND IMPORTANT NOTE

The only calculators allowed for use on this exam are those of the TI-30X series. No others.
1. [15 points]
Circle the correct answer (no partial credit) for (a) to (e).

(a) [2 points] The quality of saturated liquid is zero. (True or False)

(b) [2 points] A unit for the rate of entropy generation is kJ/kg-K. (True or False)

(c) [2 points] A steady flow system is always at steady state. (True or False)

(d) [2 points] For two different process paths between the same initial and final states, entropy generation for the two different paths is always equal. (True or False)

(e) [2 points] Which of the following devices in a simple steam power plant has the highest entropy generation? (Boiler, Condenser, Pump, Turbine)

(f) [5 points] A vapor compression heat pump cycle provides heating at the rate of 25 kW while consuming 5 kW to operate the compressor. The surrounding of the heat pump is at -3°C while the heated space is at 27°C. Is this claim possible? (Yes or No) Show supporting calculations.
2. **[30 points]** A steam power plant consists of a boiler, two adiabatic turbines, an adiabatic mixing chamber, a condenser, and two adiabatic pumps. Steam exits the boiler at 100 bar and 480°C (State 1) and expands to 7 bar and 180°C (State 2) in the high-pressure (HP) turbine. A fraction of the steam is bled off while the remaining steam expands to saturated vapor at 0.06 bar (State 3) in the low-pressure (LP) turbine and enters a condenser. Saturated liquid water at 0.06 bar (State 4) exits the condenser. An isentropic low-pressure (LP) pump increases the water pressure to 7 bar (State 5). Liquid water entering the mixing chamber is heated using the extracted steam from the high-pressure turbine and saturated liquid water at 7 bar (State 6) exits the mixing chamber. An isentropic high-pressure (HP) pump increases the water pressure to 100 bar (State 7) at the inlet of the boiler. Data at each state is provided in the table below for steady state operation; all the pressure values are absolute.

<table>
<thead>
<tr>
<th>State</th>
<th>P, bar</th>
<th>T, °C</th>
<th>h, kJ/kg</th>
<th>s, kJ/kg-K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>480</td>
<td>3323</td>
<td>6.5310</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>180</td>
<td>2799</td>
<td>6.7890</td>
</tr>
<tr>
<td>3</td>
<td>0.06</td>
<td>36.2</td>
<td>2567</td>
<td>8.3290</td>
</tr>
<tr>
<td>4</td>
<td>0.06</td>
<td>36.2</td>
<td>151.5</td>
<td>0.52082</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>n/a</td>
<td>152.2</td>
<td>0.52082</td>
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<tr>
<td>6</td>
<td>7</td>
<td>165</td>
<td>697</td>
<td>1.9918</td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td>n/a</td>
<td>?</td>
<td>1.9918</td>
</tr>
</tbody>
</table>
Problem 2 continued

(a) Determine the extracted fraction (y) at the exit of the high-pressure turbine. Report your answer in %.
(b) Calculate the total specific work output produced by the high-pressure and low-pressure turbines. Report your answer in kJ/kg.
(c) Find thermal efficiency of the cycle. Report your answer in %.
(d) Show the cycle on T-s diagram (see below) relative to the vapor dome. Label the isobars and seven states. Indicate the process directions with arrows. For water: $T_{\text{critical}} = 374^\circ\text{C}$, $P_{\text{critical}} = 221$ bar.

Identify appropriate system or systems on the sketch provided, show mass/energy interactions (EFD), list any assumptions and basic equations, and provide your solution. There is no need to re-write the given and find.

(d)
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Extra Space for Problem 2
3. [30 points] A closed, piston-cylinder device contains air at an absolute temperature of $T_1 = 300$ K and an absolute pressure of $P_1 = 100$ kPa (State 1). The air undergoes a power cycle composed of the following four processes. Data at three states is provided in the table below; all the pressure values are absolute.

- Process 1-2: Polytropic compression to $v_2 = v_1/10$ during which $Pv^{1.3} =$ constant
- Process 2-3: Heat transfer at constant volume until $T_3 = 2200$ K
- Process 3-4: Reversible and adiabatic expansion until $v_4 = v_1$
- Process 4-1: Heat transfer at constant volume back to State 1

Molecular weight of air: 28.97 kg/kmol
Use the closest values in ideal gas table; do not interpolate.

<table>
<thead>
<tr>
<th>State</th>
<th>$T$, K</th>
<th>$v$, m$^3$/kg</th>
<th>$u$, kJ/kg</th>
<th>$h$, kJ/kg</th>
<th>$s^0$, kJ/kg-K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>0.861</td>
<td>214.1</td>
<td>300.1</td>
<td>1.703</td>
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<tr>
<td>2</td>
<td>600</td>
<td>0.0861</td>
<td>434.8</td>
<td>607.2</td>
<td>2.410</td>
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<td>3</td>
<td>2200</td>
<td>0.0861</td>
<td>1873</td>
<td>2503</td>
<td>3.919</td>
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<tr>
<td>4</td>
<td>?</td>
<td>0.861</td>
<td></td>
<td></td>
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</table>

(a) Calculate the specific work for the compression and expansion processes. Report your answers in kJ/kg.
(b) Find the specific heat transfer during the compression process. Report your answer in kJ/kg.
(c) Determine the total specific entropy generation during the compression process assuming a surrounding temperature of 290 K. Report your answer in kJ/kg-K.

Identify appropriate system or systems on the sketch provided, show mass/energy interactions (EFD), list any assumptions and basic equations, and provide your solution. There is no need to re-write the given and find.
Last Name: _______________ First Name: ____________ Thermo no. _____

Extra Space for Problem 3
Last Name:________________ First Name: _____________ Thermo no. _____

Extra Space for Problem 3
4. [25 points] A piston-cylinder device initially contains 0.6 kg of water substance occupying a volume of 0.1 m³ at an absolute pressure of 10 bar (State 1). The cylinder is connected through a valve to a large supply line containing steam at an absolute pressure of 40 bar and a temperature of 500°C. The valve is opened so that steam flows into the cylinder until the volume increases to 0.2 m³ and the temperature is 240°C (State 2) while the absolute pressure in the cylinder remains constant at 10 bar throughout the process.

(a) Calculate the final mass in the cylinder and the mass of steam entering the cylinder from the supply line. Report your answers in kg.
(b) Find the work during the process. Report your answer in kJ.
(c) Determine the heat transfer during the process. Report your answer in kJ.

Identify the system, show mass/energy interactions (EFD), list any assumptions and basic equations, and provide your solution. There is no need to re-write the given and find.
Last Name:________________ First Name: _____________ Thermo no. ______

Extra Space for Problem 4