Format

The exam will begin at 9:30, and end at 10:45. The exam will have four problems. The first problem will consist of a series of short ID and/or concept questions which require a one–two sentence answer. The remaining three problems will be similar to those assigned as homework. The resources you are allowed are 1) the tables in the back of the book, and 2) four pages (front and back) of notes in your own handwriting. You may not use access any of the text chapters during the exam, and none of your notes can be printouts. Cell phones must be off and put away.

Study Points:

- At a minimum, you should be able to perform all of the assigned homework problems.
- Be able to work the problems front-to-back and back-to-front: exchange the given and required information and re-work the problems.
- Use the solutions only to check your completed work or to get you out of an intractable dead-end. If you study for this exam only by reviewing the solutions – and not actually working out problems – I can assure you that, most likely, you will do very poorly on the exam.
- Don’t stay up all night studying for the exam. Get an adequate amount of sleep. And don’t wake up at the last minute.

Concept Questions:

Be able to provide short (1–2 sentence) explanations/descriptions to the basic concepts covered in Chapters 2–4. Here is a list of example questions and review topics:

1. A system contains water at a specified temperature and pressure. Are these two properties always sufficient to specify the state of the system.

2. Be able to identify the following regions, points, and processes on a $T−v$ diagram: compressed liquid, saturated, superheated regions, saturated liquid and saturated vapor lines, critical point, and process lines corresponding to constant $T$, constant $v$, and constant $P$ processes.

3. 1 kg of water is initially in a saturated liquid state. Heat is added to the water and the water vaporizes in a constant $P$ process. At the end of the process the water is a saturated vapor. Without consulting the tables, which will require more heat to vaporize the water: a) the water is at 20°C, or b) the water is at 200°C.

4. What is the significance of the critical point for a substance?

5. Explain the basic physical assumptions inherent in the ideal gas model.

6. Explain the basic differences between an intensive and an extensive property.

7. Can a system possess heat? That is, is heat a property of the system? Explain in a sentence or two.

8. Will a process that involves no work always be a constant volume process?

9. Briefly explain the key features of and differences between work and heat.
Problem examples

The test will have three problems that are similar to your homework exercises. In working the problems, remember the following points:

- Most problems deal with a process. One of your first tasks should be to understand the nature of the process: is it constant volume, constant pressure, or does it involve some other constraint? You should be able to draw the process on an appropriate diagram (such as a $T-v$ diagram or a $P-v$ diagram).

- *Two properties fix the state:* Once you understand the process, you need to determine how to identify two independent property values at the beginning and the end of the process (and for any intermediate point in the process, if it involves multiple steps).

- Using these two properties, you need to know how to use the tables and/or formulas to get the required state information. In general, if I give you a substance and two arbitrary (and independent) properties of the substance, you should be able to determine all of the properties of the substance at the state.

- You need to be able to apply the first law and the integral formula for boundary work to get the heat and work transferred during the process.

- Water and the refrigerants are *not* ideal gases. Do not use an ideal gas formula for such substances. In particular, do not use

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

on problems involving a phase-changing substance. Use the tables.

Here are some example problems.

1. Use the water tables to fill in the missing property information in the following table:

<table>
<thead>
<tr>
<th>$T$, °C</th>
<th>$P$, kPa</th>
<th>$v$, m$^3$/kg</th>
<th>$u$, kJ/kg</th>
<th>$h$, kJ/kg</th>
<th>$x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>100</td>
<td>200</td>
<td>3000</td>
<td>0.75</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>0.5</td>
<td>3000</td>
<td>1.2</td>
<td>3000</td>
</tr>
</tbody>
</table>

Note that the fourth pair ($v$ and $x$) requires iteration in the saturation tables, and the fifth pair ($v$ and $h$) requires double interpolation (you will probably not get problems like these on this exam).

2. A piston–cylinder device contains $m = 0.1$ kg of R–134a. Initially the system is a saturated vapor ($x_1 = 1$) at $P = 100$ kPa. Heat is added to the system and the system expands in a constant–pressure process. At the end of the process a total of $Q_{1-2} = 5$ kJ has been transferred to the system. Find the final temperature of the system.

3. A container of volume $V_1 = 1$ L contains $m = 0.05$ kg water at 500 kPa. The container is placed in an evacuated chamber of volume $V_2 = 10$ L. The container is burst, and the water undergoes a free expansion to fill the chamber. At the end of the process the pressure in the chamber is $P_2 = 50$ kPa. Find the heat transfer during the process.

4. Air is contained in a piston–cylinder device. Initially the air is at $T_1 = 300$ K, $P_1 = 120$ kPa, and $V_1 = 0.1$ m$^3$. The air is then compressed in an adiabatic process, during which the state is described by $Pv^{1.4}$ = constant. The final volume of the system is $V_2 = 0.05$ m$^3$. Find the final temperature and pressure of the air and the work done on the air.

5. $m = 0.5$ kg of air is contained in a piston–cylinder device, initially at $T_1 = 300$ K and $P_1 = 200$ kPa. Heat is transferred to the air, and the air expands in a constant–pressure process. At the end of the process the volume has tripled. Find the final temperature, the work done by the air, and the heat transfer to the air. You should be able to calculate $Q_{1-2}$ using either a) the air tables, or b) a constant specific heat assumption.
6. $m = 1$ kg of water is contained in a piston–cylinder device. Initially the water is at $T_1 = 50^\circ$C and $P_1 = 50$ kPa. The piston is resting on stops, and a pressure of $P = 1$ MPa is required to float the piston. Heat is now added to the water. At the end of the process the water is a saturated vapor (quality=1). Calculate the heat transfer to the water.

7. Air is contained in a piston–cylinder apparatus that is fitted with a linear spring. Initial conditions are $T_1 = 300$ K, $P_1 = 500$ kPa, and $V_1 = 0.1$ m$^3$. The air is then expanded, and during the process the pressure varies linearly with volume. At the end of the process the temperature and pressure are $T_2 = 900$ K and $P_2 = 1$ MPa. Calculate the work and the heat transfer during the process.

8. A rigid container of volume $V = 0.1$ m$^3$ contains a saturated mixture of water at an initial pressure of 100 kPa. The system is now heated, and at $T_2 = 250^\circ$C the water becomes a saturated vapor. Find the initial quality of the water and the heat transfer during the process.

9. This problem is a reverse–engineered version of the previous one: A rigid container of volume $V = 0.1$ m$^3$ contains a saturated mixture of water at an initial pressure of 100 kPa. The system is now heated, and at some temperature $T_2$ the water becomes a saturated vapor. During the process $Q_{1-2} = 4240.3$ kJ of heat is transferred to the water. Find the final temperature of the water and the initial quality of the water. Note: this is not a simple problem; it would require a trial–and–error solution method and you probably will not encounter it on the exam. You should, though, have an idea of how you could solve it if you had to.

10. $m = 0.2$ kg of a substance is contained in a piston–cylinder device. Initial conditions are $P_1 = 150$ kPa and $V_1 = 0.225$ m$^3$. The substance is now compressed. During the process heat is transferred from the system so that the temperature remains constant. At the final state the volume is $V_2 = 0.05$ m$^3$. Calculate the work done on the system and the heat transfer from the system of the substance is a) water, and b) oxygen gas ($O_2$).

11. Air at 300 K flows into a compressor at a rate of $\dot{m} = 1$ kg/s. The work input to the compressor is 300 kW, and the rate of heat transfer from the compressor is 100 kW. Determine the outlet temperature of the air. Note: be sure you apply the correct sign (+/−) on work and heat in the first law. ($\sim 498$ K, using the tables).

12. Superheated steam at $T_1 = 500^\circ$C, $P_1 = 1$ MPa enters an adiabatic turbine. The exit is at $P_2 = 50$ kPa and a quality of 0.95. Calculate the specific work produced by the turbine. (948 kJ/kg).