Mech 222 Quiz 4 (Thermodynamics)

Commentary and Marking Guide

These notes are meant to accompany the solution Quiz4ThermoSolutions.pdf, which includes the numerical answers. For the grader and students, these notes provide background on the expectations for the questions and discussion of how part marks might be assigned (but some adjustment of the grading will occur after reviewing the student's answers.

2(10 marks) Air conditioning for Venus

Everyone should have seen this coming, and in fact in lectures the previous week I said that components of the refrigeration cycle would be on the quiz. The Study Package folder included the TS diagram used on the quiz, so there should have been no surprises there. Considering this, and the fact that we want everyone to have sharp skills for the final, we are taking a hard line on the marking for this quiz.

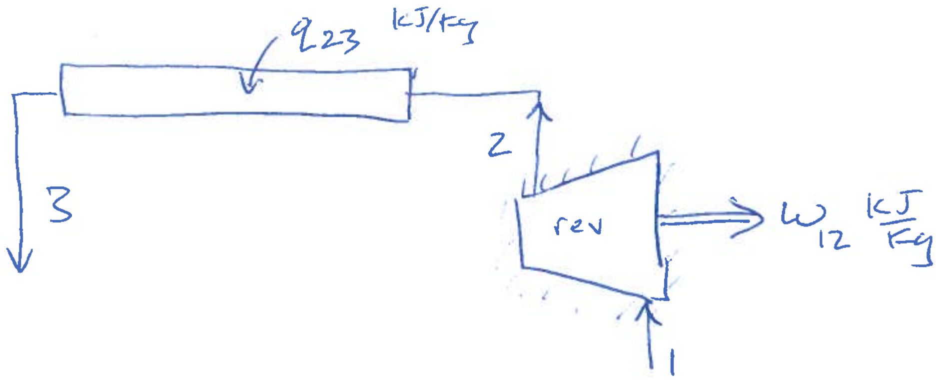
a) (3 marks) Sketch of the process. All parts have been discussed in class,
   i) 1 mark for correctly labeled condenser, with no work but heat transfer marked
   ii) 1 mark for the compressor, showing indication of work, insulation
   iii) 1 extra mark if the diagram is consistent with equations used later and theTS diagram

b) (3 marks) TS diagram. Features that must be present for 3 marks (give 1 mark only if only one of these is present)
   i) Continuous lines, not dashed lines, and correct slopes
   ii) Correct locations 1, 2, 3 (arrows not needed if flow direction in part a is given

c) (4 marks) Heat and work.
   i) 1 mark for w_{23} AND q_{12}=0
   ii) 1 mark for recognizing s_1=s_2 (using entropy balance is nice, worth sympathy points, but not needed since we have analyzed this situation many times in class)
   iii) 2 marks for applying SSSF energy balance to the two control volumes and reading off the numbers from the TS diagram. The numbers do not need to be better than +/- 30 kJ/kg

2. (10 marks) You are employed to design the cooling system for a robotic probe landing on Venus, which has a mean surface temperature of a little under 500°C. Your probe electronics are designed to operate at a little over 100°C. Inspired by your trip to Rogers Arena, you would like to use a vapor-compression refrigeration cycle, and you have finally found an application where water can be used as an effective refrigerant! For the preliminary design, you consider two portions of the ideal refrigeration cycle. There is an adiabatic, frictionless compression taking the water from state 1 (saturated vapor, $x_1 = 1, P_1 = 1$ bar) to state 2 ($T_2 = 500°C$). Next, the water is cooled isobarically from state 2 until it reaches state 3 (saturated liquid).

   (a) (3 marks) Make a diagram of the process discussed above, showing the control volumes you will analyze, labeling conditions given in the problem etc.



   (b) (3 marks) On the TS diagram of the next page, show the processes 1-2, 2-3.

   (c) (4 marks) Find the specific work and heat transfer for the two processes, that is $w_{12}, q_{12}, w_{23}, q_{23}$ all in [kJ/kg]. Be sure that the signs are consistent in your drawing above.

SSSF, $\frac{1}{\dot{m}}\frac{dE_{cv}}{dt} = 0 = q - w + (h_{in} - h_{out})$ neglect KE, PE

Process 1 → 2

$s_1 = s_2$ from 2nd Law,

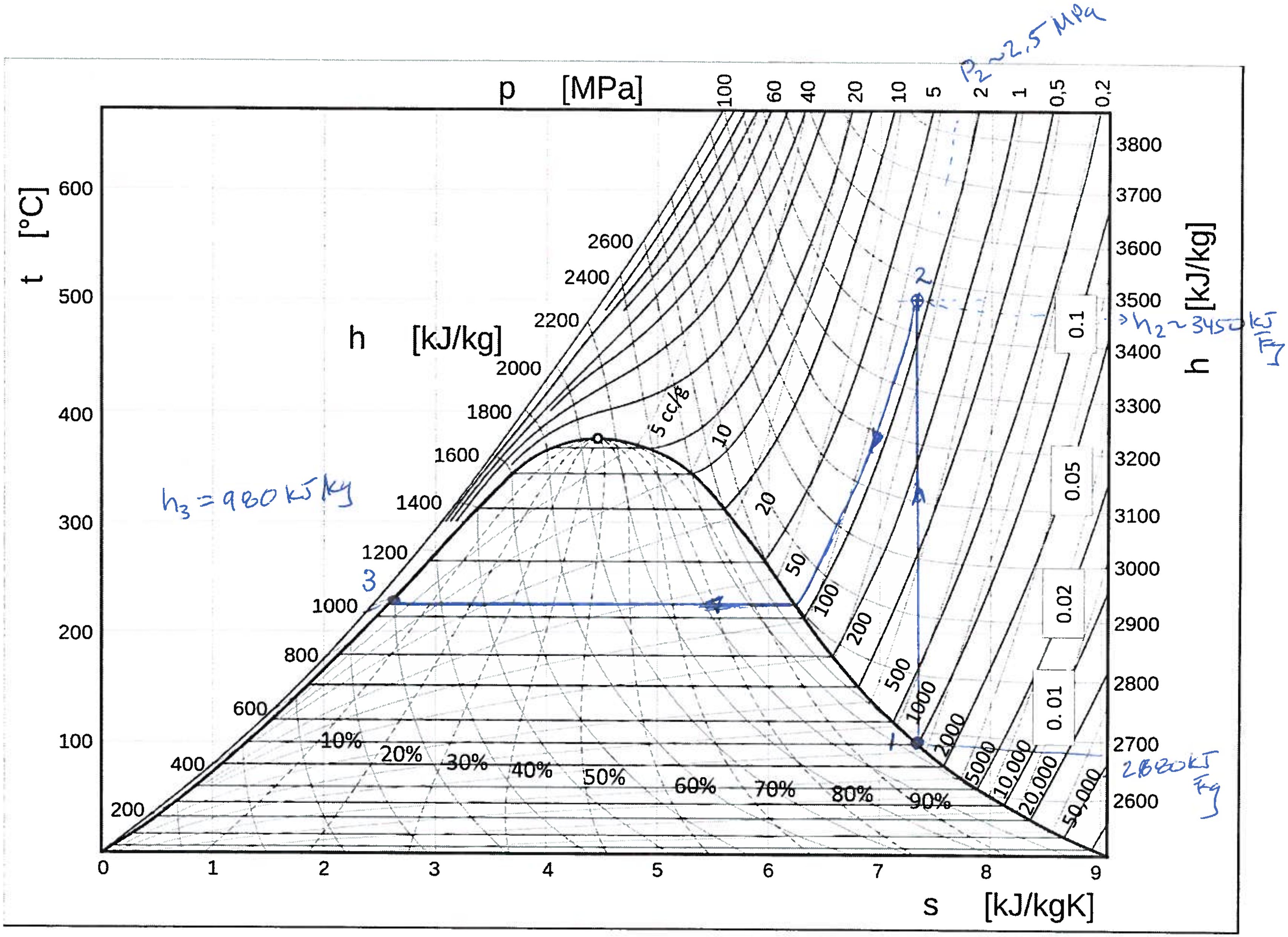
First Law gives $w_{12} = (h_1 - h_2) = 2680 - 3450 = -770 \frac{kJ}{kg}$

$q_{12} = 0$

Process 2→3 $w_{23} = 0$

$q_{23} = h_3 - h_2 = 980 - 3450 = -2470 \frac{kJ}{kg}$

(signs consistent with cooling the steam from 2→3 and compressing the steam from 1→2)



Temperature Entropy diagram for water

(By Kaboldy (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons)

Enthalpy contours in red, quality dashed blue, specific volume (g/cc =1000x m³/kg) in green, isobars in black