Queen Mary University of London

Thermodynamics 1 DEN107

Problem Set 08 (due week 10, Mon 2012mar12)

Insert the SEMS homework coverpage as 1st page; this question sheet with original signatures as the 2nd page; then attach your solutions in subsequent pages. Your solutions are due before 3.30 pm on Monday March 12th 2012 in the cabinet outside the SEMS office.

By signing below I certify that I will not obtain the teaching assistant's (TA) signature for students other than myself, and that I will not forge the TA's signature on this page. Violators will be prosecuted in accordance to QMUL procedures. Please fill in the five items below.

Student Surname:	
Student Forenames:	
Student ID (9 digits):	
Student signature:	
TA confirms tutorial attendance (signature):	

50% of the assignment grade will be deducted if the TA signature above is missing

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HINT: Observe how in all these problems I write the mathematical expressions with symbols and evaluate numerical values at the last step. You should do the same in your solutions in order to gain the maximum benefit in understanding energy and entropy flows.

Problem 1

(a) Your boss is at it again with this new idea. She has found a supply of compressed air at 400 kPa and 600 K, and has asked you to evaluate the maximum amount of power that can be extracted per 20 kg/s of compressed air flow in a complex process expanding from supply conditions to 200 kPa and 500 K. Model air as a perfect gas with $C_p = 1,004.5$ J/kg/K and $R = 286.97$ J/kg/K and assume the local reservoir is at 101.3 kPa and 298 K.
(b) Also evaluate the maximum power that can be extracted expanding 20 kg/s of compressed air from supply conditions to environmental conditions.
(c) Draw the beginning and end states of the processes in (a) and (b) above on the same T-s diagram.
Hint: Study the questions on page 94 and 95/202 in the notes.

Problem 2
Re-do problem 6-10 parts (e) and (f). For part (f) draw the block diagram of combined system AB interacting via machinery X with the reservoir R. Assume work goes into machinery X, systems AB start from state 3 and return to state 1, and there are also energy and entropy exchanges with R. Write the energy and entropy changes for the combined system AB and R, and from these prove that the minimum amount of work required to return the system to its initial state is $W_{min} = T_o \cdot DS_{ir}$

Problem 3 - evaluate all properties to 5 significant digits in this problem
Interpolate and evaluate properties of water u, h, s, v at the following states:
(s1) 101.325 kPa and 28 °C
(s2) 3.0 MPa and 435 °C
(s3) Two phase liquid at 3 MPa and quality $x = 0.65$
(a) Evaluate the above using the steam tables in the notes. In part (s2) first interpolate values between 2 and 5 MPa to obtain property values at 3 MPa, and then use the properties you evaluated at 3 MPa to interpolate again between temperatures at 400 and 500 °C to obtain properties at 435 °C
(b) Repeat the interpolation for (s2) "in the other direction". First interpolate to evaluate properties at 2 MPa and 435 °C. Then evaluate interpolate to evaluate properties at 5 MPa and 435 °C. Finally interpolate between the last two sets of values to evaluate properties at 3 MPa and 435 °C.
(c) Evaluate the properties at state s1, s2 and s3 using the National Institute of Standards and Technology workbook (careful to click the correct units, and use option "default for fluid" standard state convention) http://webbook.nist.gov/chemistry/fluid/

(d) Repeat part (c) by running the various options of the calculator in http://www.steamtablesonline.com/
(e) Assume that the NIST results in (c) are the most accurate and evaluate to 4 significant digits the percentage errors in calculating the properties of state s2 in parts (a), (b) and (d).

Problem 4
Do example 5-12 page 89 for state 2 at 4 MPa (instead of 5 MPa) using the NIST tables to evaluate properties of steam at various states. Try to repeat the solution for state 2 at 4 MPa using the steam tables in the notes, and comment on any difficulties you face.

Problem 5
Do example 2 page 112, and evaluate the expression for $\dot{m}_c = 1$ kg/s, $C_p = 1004.5$ J/kg/K, $R = 286.96$ J/kg/K and compressor pressure ratio r_c =10.

Problem 6
Do example 4 page 115, and evaluate the expression for $\dot{m}_t = 1$ kg/s, $C_p = 1004.5$ J/kg/K, $R = 286.96$ J/kg/K and turbine pressure ratio r_c =10. Use the results of problems 5 and 6 to evaluate the ratio $\dot{W}_{c,in,is}/\dot{W}_{t,ot,is}$