EML 3002C Exam 3 **ME TOOLS THERMO** **11/23/20 3:30-4:45 pm**

Page 1/3 Solutions (dommelen@eng.fsu.edu) series a

DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. A letter-size formulae sheet, handwritten by you, may be used. Put your answers on the same sheet as the question. Use at least 5 significant digits in your computations and answers where possible. You must give the units of your answers. You must write clearly. Best possible answer for multiple choice. For questions asking a number, putting the clear correct formula(s) below the question might result in partial credit even if the answer is wrong. *Not following those requirements will result in reduced or no credit.*

1. (5%) A reversible compressor compresses 0.3 kg/s of carbon dioxide gas at 300 K to a final temperature of 875 K in a process that can be taken to be polytropic with $n = 1.23$. The work needed to run this compressor is ___174.26___ kW (5 significant digits required or no credit).

2. (5%) Of the following heat engines:

   (a) $W = 0$, $Q_L = 0$, $Q_H = 0$
   (b) $W = 0$, $Q_L = 3$, $Q_H = 3$
   (c) $W = 3$, $Q_L = 3$, $Q_H = 0$
   (d) $W = 3$, $Q_L = 0$, $Q_H = 3$
   (e) $W = 1$, $Q_L = 2$, $Q_H = 3$

   _c_ violates the first law and _d_ violates the second law.

3. (5%) I have compressed liquid water at 30,000 kPa and 40°C in a well insulated piston-cylinder combination. By fooling around suitably with the piston, gently or wildly, I can turn the water into 100% saturated liquid at which ones of the following temperatures: (a) 10°C, (b) 20°C, (c) 40°C, (d) 80°C, (e) 160°C, (f) 320°C, (g) 640°C: ___c–f___.

4. (5%) If carbon dioxide is compressed from 90 kPa and 300 K to 875 K in a process that can be taken to be polytropic with $n = 1.23$, the final pressure will be ___27.566___ MPa (5 significant digits required or no credit).

5. (5%) A reversible pump is used to increase the pressure of 0.5 kg/s of liquid ammonia from 100 kPa to 800 kPa. Ignoring potential and kinetic energy changes, the power required by the pump will be ___0.57947___ kW

6. (5%) As 2 kg of solid brass cools down from 380 K to the ambient temperature of 300 K, it releases ___-60.8___ kJ of heat. The entropy created out of nothing in the total system is ___0.023011___ kJ/K.

7. (5%) A freezer must remove 50 kJ of heat from its -20°C interior. It is 25°C in the kitchen. The electricity required to do this is at least ___8.888___ kJ.

8. (33%) A piston-cylinder combination contains 3 kg of water at 400 kPa and 200°C. The water is now isothermally compressed until the entropy becomes 4 kJ/kg-K. The process is reversible.

   (a) Construct the initial phase in a very neat Ts-diagram, temperature first. Mark all lines and points used to do it with their values. State the phase. Do not put more info in the diagram than is needed to construct the phases.

   (b) Construct the final phase in a *second* Ts-diagram, meeting the same requirements as the first.

   (c) Also copy the initial state from the first diagram into the second diagram, then show the process as a fat line in the second diagram. Precisely illustrate the heat that leaks out of the water in the diagram.

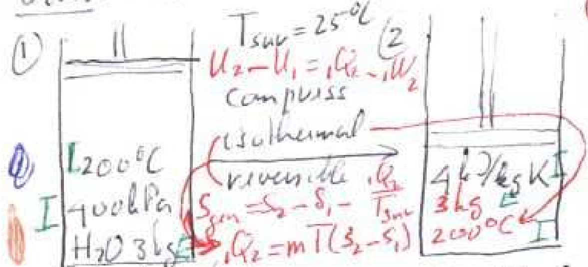
   (d) Find the heat that leaks out of the water and the work done in the compression.

   (e) If the heat ends up in the environment at 25°C, then what is the entropy generated in the complete system?

   Warning: a table may be confusing to some; look again.

   You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. *Give the source of every number.*

Given: In black



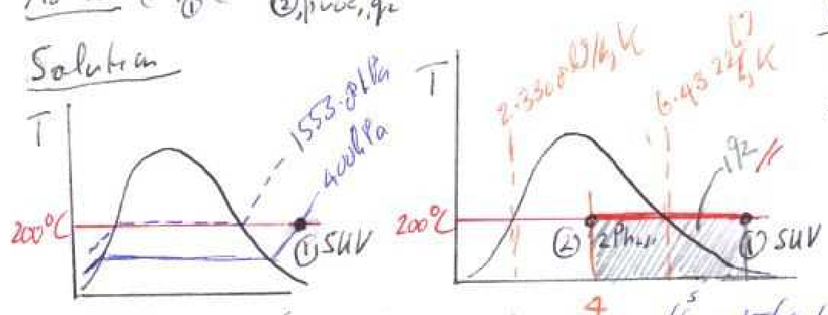
1 diagram, 1 line 1, 3 find sat, R.O., 2 plot sat, 2 line 2 rel, 2 I.D., 1 q_2 graph — 12

1 $T_2 = T_1$, 3 Read B.1.3 u_1, s_1, 1 Read B.1.1, 3 2 phase formula, 1 find x_2, 1 find u_2 — 10

1 $m_1 = m_2$, 2 heat formula, 1 find ${}_1Q_2$ units, 3 1st law, 1 find ${}_1W_2$, units, 2 2nd law, 1 find S_{gen}, units — 11

Asked: $(Ts)_1$, $(Ts)_2$, proc, q_2, ${}_1Q_2$, ${}_1W_2$, S_{gen}

Solution



SHV 1: B.1.3 @ 400 kPa, 200°C: $u_1 = 2646.83$ kJ/kg, $s_1 = 7.1706$ kJ/kgK

2P 2: B.1.1 @ 200°C: $s_f = 2.3308$, $s_{fg} = 4.1014$ kJ/kgK; $u_f = 850.64$, $u_{fg} = 1744.66$ kJ/kg

$x_2 = \frac{s_2 - s_f}{s_{fg}} = \frac{4 - 2.3308}{4.1014} = 0.40693$

use heat formula; use 1st law

$u_2 = u_f + x u_{fg} = 850.64 + 0.40693 \times 1744.66 = 1560.69$ kJ/kg

${}_1Q_2 = mT(s_2 - s_1) = 3\,\text{kg}\,(200 + 273.15)\,\text{K}\,(4 - 7.1706)\,\text{kJ/kgK} = -4500.5\,\text{kJ}$ (-3.1706)

$+4500.5\,\text{kJ} = {}_1Q_{2\,out}$

${}_1W_2 = U_1 - U_2 + {}_1Q_2 = m(u_1 - u_2) + {}_1Q_2$
$= 3\,\text{kg}\,(2646.83 - 1560.69)\,\text{kJ/kg} - 4500.5\,\text{kJ} = -1242.1\,\text{kJ}$ (1086.1)

$+1242.1\,\text{kJ} = {}_1W_{2\,on}$

${}_1S_{2gen} = m(s_2 - s_1) - {}_1Q_2/T_{surr} = 3\,\text{kg}\,(4 - 7.1706)\,\frac{\text{kJ}}{\text{kgK}} + 4500.5\,\text{kJ}/(25 + 273.15)\,\text{K}$ (-9.5118, 15.095)
$= 5.5830$ kJ/K

9. (32%) Carbon dioxide at 26.85°C and 90 kPa enters an adiabatic ideal compressor at a rate of 0.3 kg/s with a speed of 200 m/s. It exits the compressor at 30 MPa with negligible speed.
   (a) What is the diameter of the entrance pipe in cm? (Do not use the internal energy in this computation; but no sane student would do that anyway.)
   (b) Find the heat leaking out of the compressor to the surroundings and the power required to run it.
   (c) If the true compressor has a compressor efficiency of 75%, then what is the power required to run the true compressor?

   You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. *Give the source of every number.*