CM

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Name

ME301 – Applications of Thermodynamics

Exam 2

Oct 25, 2018

Circle section: **01** [6th Cloutier] **02** [5th Thom]
03 [6th Thom] **04** [5th Lui]
05 [6th Lui]

Rules:

- Closed book/notes exam.
- Two help sheets allowed. (8-1/2 x 11" sheet of paper, one side each, handwritten; may not contain worked out example problems)
- Maple, Excel, and MATLAB are allowed on your laptop, but nothing may be prepared before the exam.
- Either open property tables (hardcopies) or open Property Calculator Programs on your laptop.

Instructions:

- Show all work for complete credit.
- Work in symbols first, plugging in numbers and performing calculations last.

Problem 1	________/ 24
Problem 2	________/ 32
Problem 3	________/ 44
Total	________/100

Problem 1 [24 points]

(a) [6 pts] Two steam turbines with isentropic (adiabatic) efficiencies of $\eta_A = 1$ and $\eta_B = 0.85$ are considered for use in the same Rankine cycle. How would the various quantities compare for the two turbines?

i. Outlet specific entropies of the turbines
  - ○ $s_{out,B} < s_{out,A}$
  - ○ $s_{out,B} = s_{out,A}$
  - ○ $s_{out,B} > s_{out,A}$

ii. Outlet specific enthalpies of the turbines
  - ○ $h_{out,B} < h_{out,A}$
  - ○ $h_{out,B} = h_{out,A}$
  - ○ $h_{out,B} > h_{out,A}$

iii. Outlet pressures of the turbines
  - ○ $P_{out,B} < P_{out,A}$
  - ○ $P_{out,B} = P_{out,A}$
  - ○ $P_{out,B} > P_{out,A}$

(b) [12 pts] A mixture of fuel and oxygen is modeled as having the following molar composition: 34% CH_4 (M_{CH4}=16.04) and 66% O_2 (M_{O2}=32). Find the mass fraction of each component and the apparent (average) molar mass of the mixture.

(c) [6 pts] In a *cold air standard* Brayton cycle, the exit temperature of the air leaving the turbine is T_4=200°C and the temperature of the air leaving the compressor is T_2 =100°C.

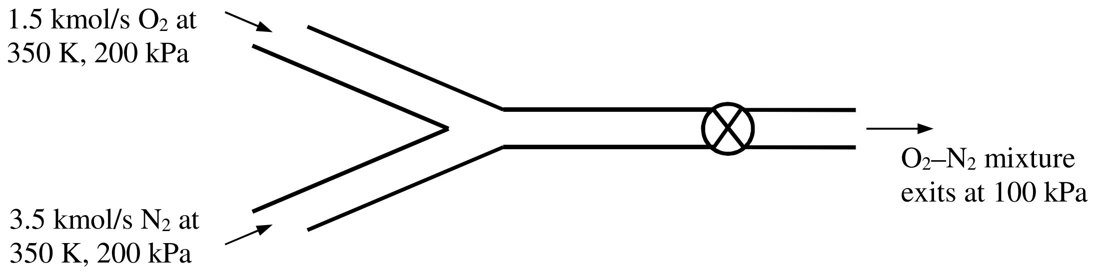
i. If the cycle makes use of an ideal regenerator, the temperature of the air entering the high pressure heat exchanger will be
   - ○ T_x = 100°C
   - ○ 100°C < T_x < 200°C
   - ○ T_x = 200°C

ii. If the cycle makes use of an non-ideal regenerator, the temperature of the air entering the high pressure heat exchanger will be
   - ○ T_x = 100°C
   - ○ 100°C < T_x < 200°C
   - ○ T_x = 200°C

iii. If the cycle is instead an *air-standard* Brayton cycle (not cold air standard), ideal regeneration would result in
   - ○ T_x = 100°C
   - ○ 100°C < T_x < 200°C
   - ○ T_x = 200°C

Problem 2 [32 points]

1.5 kmol/s of gaseous oxygen at 350 K and 200 kPa is mixed with 3.5 kmol/s of gaseous nitrogen at 350 K and 200 kPa. The mixture stream is then throttled to standard room pressure at 100 kPa through a valve.



(a) If the process is *adiabatic*, determine the mixture temperature at the exit.

(b) Determine the entropy generation rate during the mixing-throttling process, in kW/K.

Clearly document your solution for full credit.

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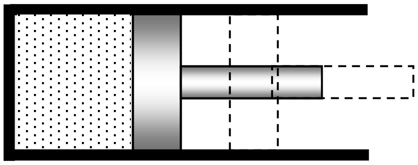
Problem 3 [44 points]

A piston-cylinder operates on the Worst-Efficiency-Ever Cycle (WEEC) with steam as the working fluid. The cycle consists of the following three processes:



State (1) to (2): Constant volume heat addition
State (2) to (3): Reversible, adiabatic expansion
State (3) to (1): Constant pressure heat rejection

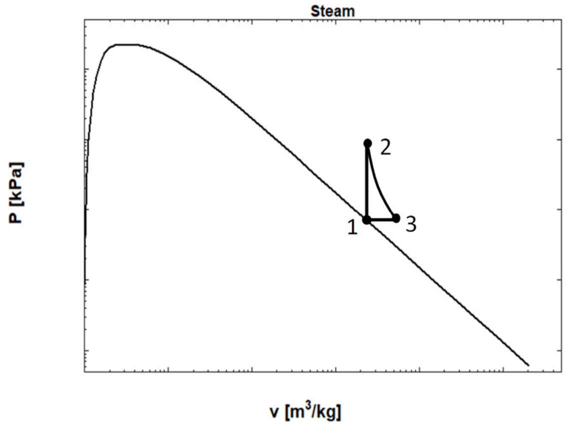
At the beginning of the heat addition process, 0.1 kg of water exists as a saturated vapor at 100 kPa.

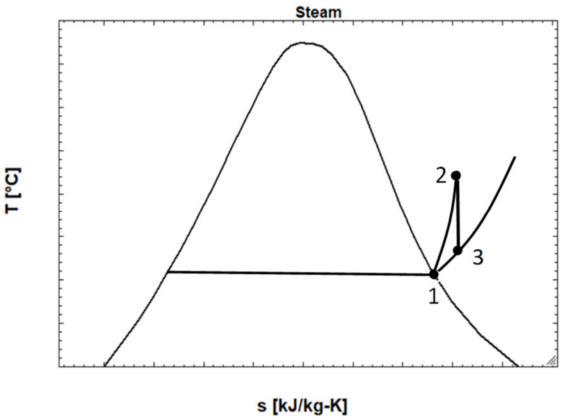
Process	*W* (kJ)	*Q* (kJ)
(1) → (2)		27.29
(2) → (3)		
(3) → (1)		

(a) Find the maximum cycle temperature.

(b) Fill in the table with the work and heat transfer associated with each requested process. (**Note: show all work for full credit.**)

(c) Calculate the cycle efficiency.





Length

1 ft = 12 in = 0.3048 m = 1/3 yd
1 m = 100 cm = 1000 mm = 39.37 in = 3.2808 ft
1 mile = 5280 ft = 1609.3 m

Mass

1 kg = 1000 g = 2.2046 lbm
1 lbm = 16 oz = 0.45359 kg
1 slug = 32.174 lbm

Temperature Values

(T/K) = (T/ °R) / 1.8
(T/K) = (T/ °C) + 273.15
(T/°C) = [(T/ °F) – 32]/1.8
(T/°R) = 1.8(T/K)
(T/°R) = (T/ °F) + 459.67
(T/ °F) = 1.8(T/ °C) + 32

Temperature Differences

$(\Delta T/^\circ R) = 1.8(\Delta T/K)$
$(\Delta T/^\circ R) = (\Delta T/^\circ F)$
$(\Delta T/K) = (\Delta T/^\circ C)$

Volume

1 m^3 = 1000 L = 10^6 cm^3 =10^6 mL = 35.315 ft^3
= 264.17 gal
1 ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3
1 gal = 0.13368 ft^3 = 0.0037854 m^3

Volumetric Flow Rate

1 m^3/s = 35.315 ft^3/s = 264.17 gal/s
1 ft^3/s = 1.6990 m^3/min = 7.4805 gal/s
= 448.83 gal/min

Force

1 N = 1 kg·m/s^2 = 0.22481 lbf
1 lbf = 1 slug·ft/s^2 = 32.174 lbm·ft/s^2
= 4.4482 N

Pressure

1 atm = 101.325 kPa = 1.01325 bar
= 14.696 lbf/in^2
1 bar = 100 kPa = 10^5 Pa
1 Pa = 1 N/m^2 = 10^{-3} kPa
1 lbf/in^2 = 6.8947 kPa = 6894.7 N/m^2 ;
[lbf/in^2 = "psi"]

Energy

1 J = 1 N·m
1 J = 1 Pa·m^3
1 kJ = 1000 J = 737.56 ft·lbf = 0.94782 Btu
1 Btu = 1.0551 kJ = 778.17 ft·lbf
1 ft·lbf = 1.3558 J

Energy Transfer Rate

1 kW = 1 kJ/s = 737.56 ft·lbf/s = 1.3410 hp = 0.94782 Btu/s
1 Btu/s = 1.0551 kW = 1.4149 hp
= 778.17 ft·lbf/s
1 hp = 550 ft·lbf/s = 0.74571 kW
= 0.70679 Btu/s

Specific Energy

1 kJ/kg = 1000 m^2/s^2
1 Btu/lbm = 25037 ft^2/s^2
1 ft·lbf /lbm = 32.174 ft^2/s^2

Other useful information	SI	USCS
Universal Ideal Gas Constant: $\bar{R}$	= 8.314 kJ/(kmol-K)	= 1545 (ft-lbf)/(lbmol-R) = 1.986 Btu/(lbmol-R)
Acceleration of Gravity: g	= 9.810 m/s^2	= 32.174 ft/s^2