CM [1 pt]

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Name

ME301 – Applications of Thermodynamics

Circle section: **01** [4th Mech] **02** [5th Mech]
03 [4th Thom] **04** [5th Thom]
05 [4th Lui]

Exam 2

Oct 26, 2017

Rules:

- Closed book/notes exam.
- Two help sheets allowed. (8-1/2 x 11" sheet of paper, one side, 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.

+1 for CM

Problem 1	______/ 32
Problem 2	______/ 37
Problem 3	______/ 30
Total	______/100

PROBLEM 1 [32 points]

(a) [14 pts] Indicate whether each of the following statements is true or false.

True | False One of the air standard assumptions is to model an open system cycle as a closed system.

True | False Increasing compression ratio increases the efficiency of an Otto cycle.

True | False The specific entropy of a fluid exiting a steady-state, adiabatic turbine increases as turbine efficiency increases.

True | False Heat pump and refrigeration cycles form clockwise plots on a T-s diagram.

True | False Power cycles form (heat engines) form clockwise plots on a P-v diagram.

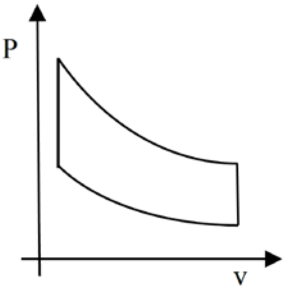
True | False According to Dalton's model, mixtures of ideal gases can also be assumed to be ideal gases.

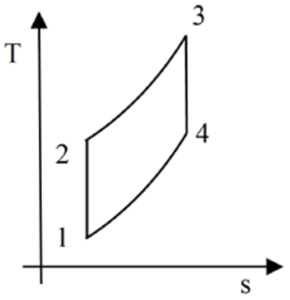
True | False Partial pressure is calculated by multiplying mass fraction with total pressure.

(b) [7 pts] Given the P-v and T-s diagrams at the right,

i. add state numbers to the P-v diagram that correspond with the states of the T-s diagram.

ii. Show where the new state point 2 would be on each diagram if the compression ratio were increased while keeping the initial volume the same.





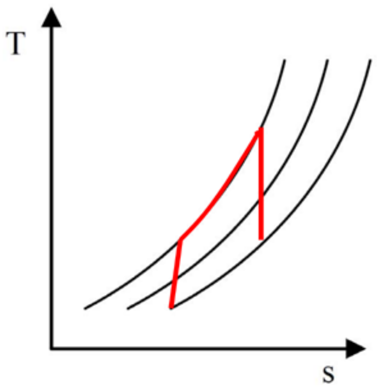
(c) [2 pts] When finding specific entropy changes for one component of an ideal gas mixture, what pressure should you use?

○ Mixture pressure
○ Partial pressure of the component
○ It doesn't matter, either one will always work.
○ None of the above—specific entropy of an ideal gas is a function of temperature only

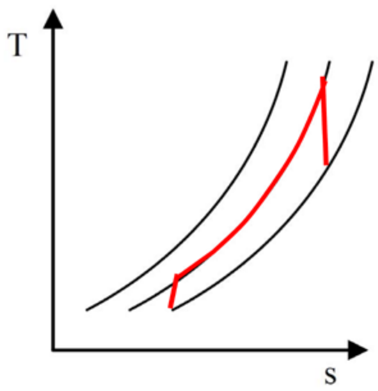
(d) [3 pts] Match the component of a refrigeration cycle with the correct description.

___ Throttling valve	i. can never be reversible
___ Compressor	ii. relates to refrigeration capacity
___ Condenser	iii. relates to the denominator of the coefficient of performance

(e) [6 pts] Compare the *T-s* diagrams of two gas turbine cycles (two Brayton cycles) as shown. Making use of *cold air standard assumptions*, indicate which cycle better fits each description.



Cycle A



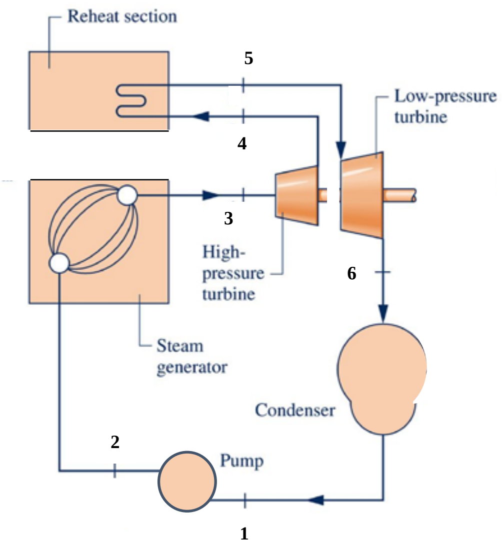
Cycle B

Circle the better choice

i. Has a higher pressure ratio:	A	B
ii. Has a higher turbine inlet temperature:	A	B
iii. Has a higher cycle efficiency:	A	B
iv. Could makes use of a regenerator:	A	B

PROBLEM 2 [37 points]

A Rankine cycle is modified with reheat as shown in the figure. The flowrate of steam is $\dot{m}$ = 1.5 kg/s. The isentropic efficiencies of the pump and low-pressure turbine are $\eta_P = 0.7$ and $\eta_{HPT} = 0.8$, respectively. Other operating conditions are given in the figure, and some property information is given in the table below.

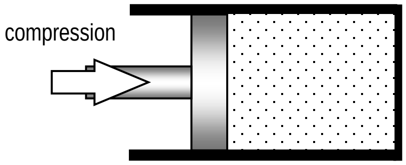


$$\dot{Q}_{generator} = 5679 \text{ kW}$$
$$\dot{W}_{LPT} = 2027 \text{ kW}$$

State	P [kPa]	T [°C]	x	v [m³/kg]	u [kJ/kg]	h [kJ/kg]	s [kJ/kg·K]
1		20.0	0.0	0.001018	83.83	83.84	0.2962
2s	8000	20.1		0.001018	83.83	91.83	
2	8000						
3	8000	700		0.0548	3443	3881	7.280
4s	1000			0.2796	2865	3145	
4	1000						7.506
5	1000	700		0.4478	3476	3924	8.274
6s			0.95	55.07	2294	2422	
6				61.55	2429	2573	8.783

(a) Find the inlet pressure to the pump in kPa.
(b) Calculate the power into the pump in kW.
(c) Calculate the power out of the high-pressure turbine in kW.
(d) Calculate the rate of heat transfer into the reheat section in kW.
(e) Calculate the cycle efficiency.
(f) Calculate the isentropic efficiency of the low-pressure turbine..

Problem 3 [30 points]



Two kilograms of a two-component mixture of 20% of methane (CH_4) and 80% of oxygen (O_2) by mass is compressed **isothermally** in a closed piston cylinder from an initial pressure and temperature of P_1 = 100 kPa and T_1=25°C to a final pressure of P_2 = 500 kPa.

Treat the mixture as an ideal gas with variable specific heats. For reference, the molar masses of methane and oxygen are M_{CH4} = 16.04 kg/kmol and M_{O2} = 32.00 kg/kmol, respectively, and $\bar{R}$ = 8.314 kJ/kmol·K.

(a) Determine the molar composition (i.e., the mole fractions) of the mixture.

(b) Sketch the compression process on both *P–v* and *T–s* diagrams.

(c) Find the following properties and changes in properties:

- i. R_{mix} in kJ/kg·K
- ii. $v_{1,O2}$ in m³/kg
- iii. $(\bar{h}_2 - \bar{h}_1)_{\mathrm{CH4}}$ in kJ/kmol
- iv. $(\bar{s}_2 - \bar{s}_1)_{\mathrm{mix}}$ in kJ/kmol·K

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

$(T/K) = (T/^{o}R) / 1.8$
$(T/K) = (T/^{o}C) + 273.15$
$(T/^{o}C) = [\,(T/^{o}F) - 32\,]/1.8$
$(T/^{o}R) = 1.8(T/K)$
$(T/^{o}R) = (T/^{o}F) + 459.67$
$(T/^{o}F) = 1.8(T/^{o}C) + 32$

Temperature Differences

$$(\Delta T/^{o}R) = 1.8(\Delta T/K)$$
$$(\Delta T/^{o}R) = (\Delta T/^{o}F)$$
$$(\Delta T/K) = (\Delta T/^{o}C)$$

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 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
1 J = Pa·m^3

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