

DEPARTMENT OF CHEMICAL ENGINEERING AND MATERIALS SCIENCE

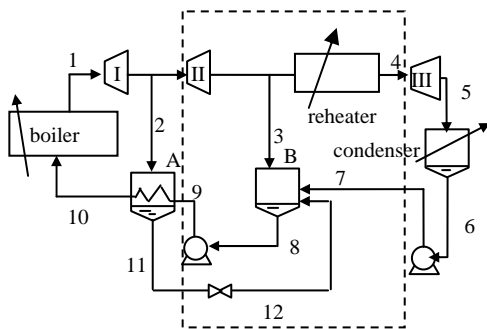
ChE 321: Chemical Engineering Thermodynamics
 Part I, February 23, 2011, Open Book, Closed Notes

Spring 2011

General Directions

- Submit all problems in the order of the exam
- Do all work on exam pages. Use the page back if necessary or request more paper.
- For steam table interpolations, write down all values used for interpolation even if you use a calculator.
- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

1. Answer the following question using the schematic below using adiabatic turbines. The table is provided for your convenience. NOT ALL STATES ARE NEEDED.



	P(MPa)	T(C)	H(kJ/kg)	S(kJ/kgK)
1	8	600	3642.4	7.0221
2	1.2		3100.	
3	0.2	150		
4	0.2	300		
5	0.01			
6	0.01		191.8	
7	0.2		192.0	
8				
9			515	
10			763.8	
11			798.3	
12				

(a) (10) Determine the pressures for streams 8-12 and enter them in the table.

(b) (10) Find H_3 , H_4 , H_{12} , H_8 , and Q_{reheater} (kJ/kg).

(c) (20) Find the work done by adiabatic turbine III and the quality of the outlet if the efficiency is 80%.

(d) (10) Write the energy balance around preheater B. Eliminate all mass flow rates except for m_3/m_1 and m_2/m_1 . Rearrange to solve for m_3/m_1 . Leave the enthalpies as variables; do not calculate the final number.

(e) (10) For the dotted boundary, write the simplified energy balance for the steam/water. Do not include Q or W for equipment where the values are zero for the designated boundary. If Q and W are relevant, indicate with subscripts the relevant equipment. Insert all relevant stream flow rates into the balance. Do not combine with other balances.

Michigan State University

DEPARTMENT OF CHEMICAL ENGINEERING AND MATERIALS SCIENCE

ChE 321: Chemical Engineering Thermodynamics
Part II, Open Book, Closed Notes

Spring 2011

General Directions

- Submit all problems in the order of the exam
- Do all work on exam pages. Use the page back if necessary or request more paper.
- For steam table interpolations, write down all values used for interpolation even if you use a calculator.
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2. Ethane is to be compressed from 0.1 MPa and 300K to 0.7 MPa in an adiabatic piston/cylinder. Assume ethane is an ideal gas with $C_p = 6.3R$.

(10) Determine the final T, W, ΔU , ΔH , if the compression is 80% efficient.

3. (15) A simple derivative manipulation is applied to each of the starting expressions in the left column below. Some of the manipulations may involve errors. Indicate whether the ending expression in each row is valid or invalid. Work that is shown in the scratch area is necessary for partial credit.

Starting Expression	Ending Expression	Indicate Valid or Invalid
$\left(\frac{\partial A}{\partial P}\right)_T$	$\left(\frac{\partial A}{\partial P}\right)_T = T\left(\frac{\partial V}{\partial T}\right)_P - P\left(\frac{\partial V}{\partial P}\right)_T$	
$\left(\frac{\partial S}{\partial G}\right)_T$	$\left(\frac{\partial S}{\partial G}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial P}{\partial G}\right)_T = -\frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$	
$\left(\frac{\partial A}{\partial P}\right)_T$	$\left(\frac{\partial A}{\partial P}\right)_T = -\left(\frac{\partial A}{\partial T}\right)_P / \left(\frac{\partial P}{\partial T}\right)_A$	

3. CO₂ sequestration is a topic of considerable debate due to the energy requirements. Suppose that CO₂ has been purified from a flue gas and is available at 300 K and 0.1 MPa.

(a) (5) One possibility for sequestration is to compress the CO₂ for storage. Using the attached chart, determine the work required to compress the CO₂ in a single stage if the reversible temperature rise is limited to 100K in a steady-state adiabatic compressor with an efficiency of 90%. Mark the chart clearly and submit it with your work.

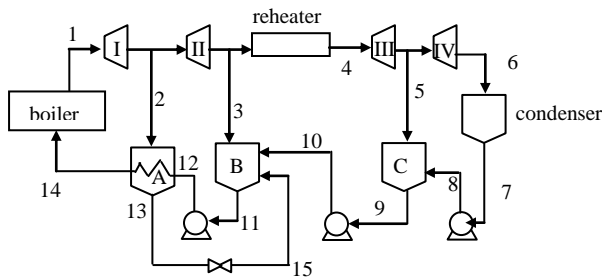
(b) (10) Another proposal for sequestration is to liquefy CO₂ to a saturated liquid at 300K. From the initial condition of 300 K and 0.1 MPa, determine the minimum work and minimum heat transfer necessary (kJ/kg) for a steady-state flow process. Heat may be transferred to the surroundings at 295K. Though the outlet condition in part (a) is far from the target conditions of (b) compare the magnitude of the work.

Table of saturated CO₂ properties, and T-S diagram

General Instructions

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- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

These problems consider the combined reheat and regenerative cycle shown below. Unit A is a closed feedwater preheater. Units B and C are open feedwater preheaters. The turbines and pumps are adiabatic. NOTE: ONLY SOME STREAMS ARE REQUIRED TO SOLVE THE PROBLEMS. DO NOT TAKE TIME TO FIND ALL STATES!



	P(MPa)	T(C)	H (kJ/kg)	S(kJ/kg-K)
1	6	500	3423.1	6.8826
2	2	350	3137.7	6.9583
3	0.6		3062.0	7.3740
4	0.6	450		
5	0.2			
6	0.01			
7	0.01			
8				
9				
10				
11	0.6	158.83	670.38	
12	6		678.4	
13	2		908.5	
14	6	200	857.5	
15	0.6			

1. (5) Determine P_8 , P_9 , P_{10}

2. (10) Determine the quality of stream 15 and the entropy generated (kJ/kg-K).

3. (5) Verify the tabulated enthalpy of stream 14.

3. (20) Turbines III and IV are each 85% efficient. Determine the work produced in each turbine (kJ/kg). Provide the numbers used for interpolation.

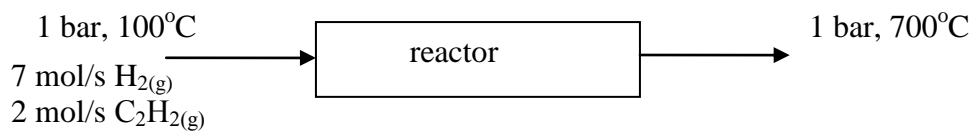
4. (10) Determine the mass flowrate ratio m_2/m_1 .

Part II. February 24, 2010, OPEN BOOK, CLOSED NOTES

General Instructions

- Submit all problems in the order of the exam.
- Do all work on exam pages. Use back if necessary.
- For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

3. Acetylene ($\text{C}_2\text{H}_{2(g)}$) is hydrogenated (reacting with $\text{H}_{2(g)}$) to form ethane ($\text{C}_2\text{H}_{6(g)}$) in a catalytic reactor under conditions shown below. Conversion of C_2H_2 is 83%.



- (a) (10) Balance the reaction and determine the outlet flow (mol/s) of each component.

- (b) (10) Determine the standard heat of reaction.

- (c) (15) Complete the table of enthalpies at the inlet and outlet conditions from the figure. Use heat capacities from the back flap of the text and assume that they are T -independent. Calculate the enthalpy values in a manner that they can be properly used in the energy balance in part (d) below. Provide the formula and intermediate values for at least one specie in each stream.

Specie	C_p/R	$C_p(\text{J/mol-K})$	$H^{\text{in}} (\text{J/mol})$	$H^{\text{out}} (\text{J/mol})$
$\text{H}_{2(\text{g})}$				
$\text{C}_2\text{H}_{2(\text{g})}$				
$\text{C}_2\text{H}_{6(\text{g})}$				

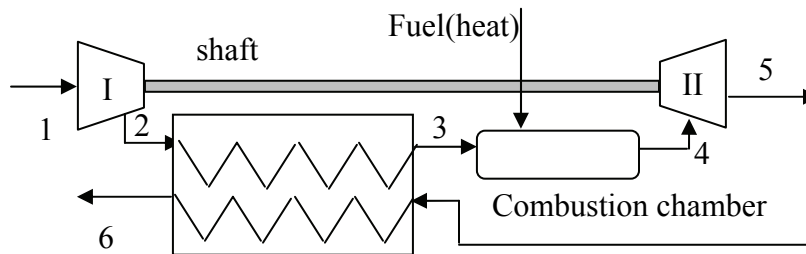
- (d) (10) Determine the required heat transfer (J/s) in the reactor to maintain the states given in the figure. Is heat added or removed?

Part I. February 25, 2009, OPEN BOOK, CLOSED NOTES

General Instructions

- Submit all problems in the order of the exam.
- Do all work on exam pages. Use back if necessary.
- For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

1. A modified Brayton cycle operates using the regenerator as shown in the schematic below. The cycle is to assume the ideal gas is applicable. The number of moles produced by combustion are to be ignored so that the molar flow rate of 4 is the same as 3, as an approximation. $C_p = 3.506R$, independent of temperature. $P_1 = P_5 = P_6 = 0.1$ MPa, and $P_2 = P_3 = P_4 = 0.6$ MPa, and $\dot{n}_1 = 50$ mol/s.



(a) (5) If $T_1 = 298\text{K}$ and the adiabatic compressor is 85% efficient. Find T_2 and $\underline{W}_{s,I}$ (kW).

(b) (10) If $T_4 = 973\text{K}$ and $T_5 = 640\text{K}$, determine the efficiency of the adiabatic turbine.

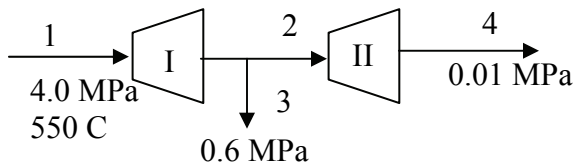
(c) (10) If $T_6 = 563\text{K}$, find T_3 .

2. (10) A simple derivative manipulation is applied to each of the starting expressions in the left column below. Some of the manipulations may involve errors. Indicate whether the ending expression in each row is valid or invalid. Work that is shown in the scratch is necessary for partial credit.

Starting Expression	Ending Expression	Indicate valid or invalid
(a) $\left(\frac{\partial G}{\partial S}\right)_T$	$-V\left(\frac{\partial T}{\partial V}\right)_P$	
(b) $\frac{\left(\frac{\partial H}{\partial P}\right)_T}{\left(\frac{\partial V}{\partial T}\right)_P}$	$-T + V\left(\frac{\partial T}{\partial V}\right)_P$	

Scratch work area:

3. Adiabatic steam turbines I and II are each 90% efficient.



(a) (10) Determine the work produced in turbine I (kJ/kg). Provide the values used for any interpolation.

(b) (10) Determine the work produced in turbine II (kJ/kg). Provide the values used for any interpolation.

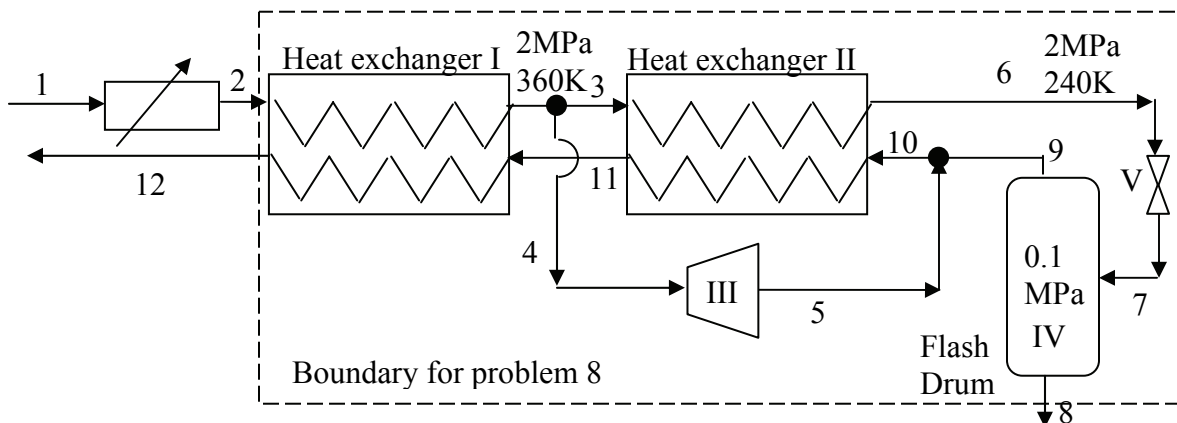
(c) (5) If $m_3/m_1 = 0.08$, find the work total produced by the turbine system per kg of flow of stream 1.

Part II. February 25, 2009, OPEN BOOK, CLOSED NOTES

General Instructions

- Submit all problems in the order of the exam.
- Do all work on exam pages. Use back if necessary. Submit all exam pages and the PH chart.
- For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

MARK YOU ANSWERS CLEARLY ON THE CHART AND SUBMIT WITH YOUR WORK.



The next few problems consider the liquefaction cycle shown above. The expander is adiabatic and 90% efficient. The flash drum is adiabatic. The operating fluid is refrigerant ethane (chart attached).

4. (5) How many unique ethane flow rates are involved in the problem? _____.

5. (10) Find m_8/m_6 and m_9/m_6 .

6.(10) If the expander is 90% efficient and adiabatic, determine the work produced by the expander (kJ/kg).

7. (5) Provide the energy balance at the mixing point between 9 and 10.

8. (10) For the dotted boundary, write the simplified energy balance for ethane. Do not include Q and W for equipment where the values are zero for the boundary. Insert all relevant stream flow rates into the balance. If Q and W are relevant, indicate with subscripts the relevant equipment (e.g. I, II, III, etc.). Do not rearrange the balance or combine with other balances. Use intensive and extensive notation properly.

ethane chart

DEPARTMENT OF CHEMICAL ENGINEERING AND MATERIALS SCIENCE

ChE 321: Chemical Engineering Thermodynamics

Spring 2008

Part I. February 19, 2008, OPEN BOOK, CLOSED NOTES

General Instructions

- Submit all problems in the order of the exam.
- Do all work on exam pages. Use back if necessary. Submit all exam pages and the PH chart.
- For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

1. Methane (1.25 moles) is compressed isothermally in a piston/cylinder. The initial temperature and pressure are 20°C and 0.1 MPa. The final pressure is 0.5 MPa. Assume $C_p/R = 4.298$ is independent of temperature and model the fluid as an ideal gas.

(a) (5) Determine the total work required in (kJ).

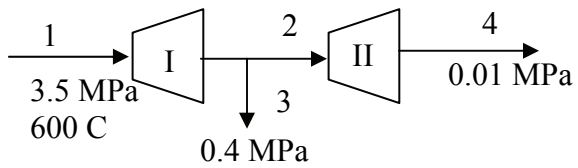
(b) (10) Determine ΔS (J/molK) and ΔU (J/mol).

2. (10) A simple derivative manipulation is applied to each of the starting expressions in the left column below. Some of the manipulations may involve errors. Indicate whether the ending expression in each row is valid or invalid. Work that is shown in the scratch is necessary for partial credit.

Starting Expression	Ending Expression	Indicate valid or invalid
(a) $\left(\frac{\partial T}{\partial V}\right)_G$	$\left(\frac{\partial T}{\partial V}\right)_G = -\left(\frac{\partial T}{\partial G}\right)_V \left(\frac{\partial G}{\partial V}\right)_T$	
(b) $dA = TdS - PdV$	$\left(\frac{\partial A}{\partial V}\right)_P = C_P \left(\frac{\partial V}{\partial T}\right)_P - P$	

Scratch work area:

3. Adiabatic steam turbines I and II are each 85% efficient.



(a) (10) Determine the work produced in turbine I (kJ/kg). Provide the values used for any interpolation.

(b) (10) Determine the work produced in turbine II (kJ/kg). Provide the values used for any interpolation.

(c) (10) If $m_3/m_1 = 0.08$, find the work total produced by the turbine system per kg of flow of stream 1.

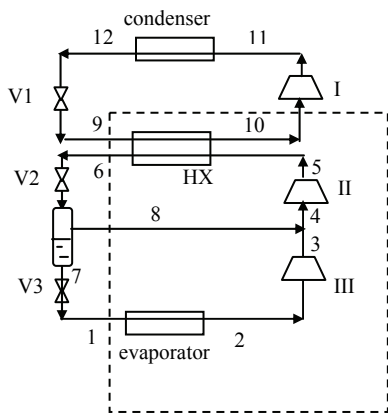
Part II. February 19, 2008, OPEN BOOK, CLOSED NOTES

General Instructions

- Submit all problems in the order of the exam.
- Do all work on exam pages. Use back if necessary. Submit all exam pages and the PH chart.
- For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

The next few problems consider the cascade refrigeration cycles shown below. The compressors are adiabatic and 75% efficient. The operating fluid is refrigerant 22 (chart attached). HX is an evaporator for the upper cycle and a condenser for the lower cycle.

MARK YOUR ANSWERS CLEARLY ON THE CHART AND SUBMIT WITH YOUR WORK. The dotted line is a boundary used in problem 7.



	P(MPa)	T(K)	H (kJ/kg)	S(kJ/kg-K)
1	0.12			
2	0.12		268	
3'				
3			297	
4				
5'				
5				
6	0.8			
7	0.31	260		
8	0.31	260		
9	0.6			
10				
11'				
11				
12		320		

4. (10) Find H_{11} , mark it on the plot and label it, and report here the values of H_{11} and T_{11} .

5. (10) Locate state 6 on the graph and mark the point clearly. Find q out of valve V2, and determine the flowrate of m_8 and m_7 if $m_6 = 40$ kg/h.

6. (15) Find H_8 and H_4 if $m_6 = 40$ kg/h.

7. (10) For the dotted boundary, write the simplified energy balance for refrigerant 22. All compressors are adiabatic. Insert all relevant stream flow rates into the balance. If Q and W are relevant, indicate with subscripts the relevant equipment (e.g. I, II, III, evap, cond, HX, flash). Do not rearrange the balance or combine with other balances.

R22 chart

Michigan State University

DEPARTMENT OF CHEMICAL ENGINEERING AND MATERIALS SCIENCE

ChE 321: Chemical Engineering Thermodynamics

Spring 2007

Exam 1 – Part I, Version A - Open Book, closed notes, 2/20/07,
SUBMIT ALL ORIGINAL PAGES.

1. An ideal gas is compressed isothermally in a piston/cylinder from 0.1 MPa to 4 MPa. The cylinder contains 1.2 mol at 340 K. For the ideal gas, $C_p/R = 8.851$ is independent of T.

(a) (10) Determine the amount of work performed (kJ) and the reversible change in internal energy, ΔU (kJ) if the device is reversible.

(b) (5) What is the required heat transfer if the device in part (a) has an efficiency of 80%?

2. (10) A simple derivative manipulation is applied to each of the starting expressions in the left column below. Some of the manipulations may involve errors. Indicate whether the ending expression in each row is valid or invalid. Work that is shown in the scratch area may be helpful for partial credit.

Starting Expression	Ending Expression	Indicate Valid or Invalid
$\left(\frac{\partial S}{\partial P}\right)_V$	$\left(\frac{\partial S}{\partial P}\right)_V = \frac{-C_V}{T} \left(\frac{\partial T}{\partial P}\right)_V$	
$\left(\frac{\partial T}{\partial V}\right)_H$	$\left(\frac{\partial T}{\partial V}\right)_H = -\left(\frac{\partial T}{\partial H}\right)_V \left(\frac{\partial V}{\partial H}\right)_T$	
$\left(\frac{\partial A}{\partial T}\right)_P$	$\left(\frac{\partial A}{\partial T}\right)_P = C_P - P \left(\frac{\partial V}{\partial T}\right)_P$	

Name _____

Ethylene Chart

Michigan State University

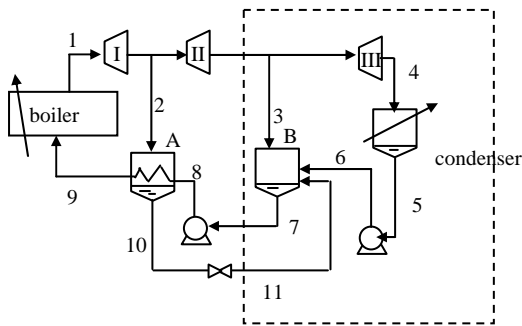
DEPARTMENT OF CHEMICAL ENGINEERING AND MATERIALS SCIENCE

ChE 321: Chemical Engineering Thermodynamics

Spring 2007

Exam 1 – Part II, Open Book, closed notes, 2/20/07,
SUBMIT ALL ORIGINAL PAGES.

The next few problems consider the combined reheat and regenerative cycle shown below. Unit A is a closed feedwater preheater. Unit B is an open feedwater preheater. The turbines and pumps are adiabatic.



	P(MPa)	T(C)	H (kJ/kg)	S(kJ/kg-K)
1	2.5	500		
2	0.5	300	3064.6	
3	0.2	200	2870.7	
4	0.01			
6			192.1	
7			504.7	
11			640.1	

7. (5) How many unique flowrates exist in the process? _____
How many unique pressures? _____

8. (10) The mass flow ratio $m_2/m_1 = 0.035$. Find m_3/m_1 .

9. (10) Determine the enthalpy of stream 8. The pumps are 80% efficient.

10. (10) If turbine III is 85% efficient, determine the work per kg of stream 4 flow.

12. (5) Write the energy balance for the boundary indicated by the dotted line. Use intensive fluid properties along with mass flowrates in your answer. For work, use $m_i W_S$ instead of \underline{W}_S ; the same applies for heat. Eliminate terms that are not relevant. You do not need to combine with other balances.

February 22, 2006, OPEN BOOK, CLOSED NOTES, PART I

General Instructions

- Submit all problems in the order of the exam.
 - Do all work on exam pages. Use back if necessary. Submit all exam pages
 - For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
 - Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.
- An ideal gas flows through a steady-state adiabatic compressor ($\eta = 0.8$). The inlet is 298K and 0.1 MPa. The outlet is 0.4 MPa. The temperature-independent heat capacity is $C_p = 29.1 \text{ J/molK}$.
 - (10) Determine the reversible outlet temperature.
 - (10) Determine the actual outlet temperature.
 - (5) Determine the size of compressor (kW) necessary to process 150 mol/min.
 - The refrigeration cycle below uses R-500 (PH diagram attached). Stream 1 is saturated vapor at 0.2 MPa and stream 4 is saturated liquid at 0.8 MPa. The compressor is adiabatic ($\eta = 0.85$). Heat exchanger I serves increase the temperature from 1 to 2 and decrease the temperature from 4 to 5. Stream 2 is at 280K and 0.2MPa.

A table is provided for convenience on pg 2. The problem may not require all values.

Stream	T(K)	P (MPa)	H(kJ/kg)	S(kJ/kg-K)
1		0.2		
2	280	0.2		
3'				
3				
4		0.8		
5				
6				

Mark your points clearly on the attached chart.

(a) (15) Determine the work done by the compressor (kJ/kg).

(b) (5) Determine the enthalpy of stream 5.

(c) (5) Determine the quality of stream 6 and the heat transfer in the evaporator (kJ/kg).
(Note: if you were unable to locate H5 in part (b), assume a value of 80 kJ/kg for this calculation).

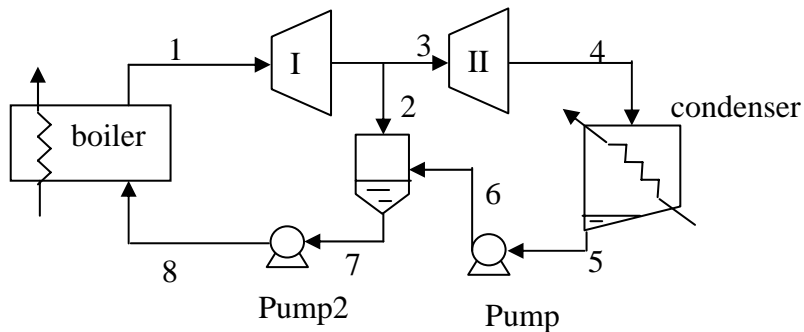
(d) (10) For the dotted boundary, write the energy balance for R-500. Insert all relevant stream numbers into the balance. If heat and work are relevant for the boundary, use intensive Q 's and W 's. Do not rearrange the balance or combine with other equations.

R-500 chart

February 22, 2006, OPEN BOOK, CLOSED NOTES, PART II

General Instructions

- Submit all problems in the order of the exam.
 - Do all work on exam pages. Use back if necessary. Submit all exam pages
 - For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
 - Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.
3. A power plant uses a two stage turbine with a open feedwater preheater as shown below. Steam exits the boiler/superheater at 500°C and 3 MPa. The outlet of the first adiabatic turbine ($\eta = 0.8$) is at 0.3 MPa. The outlet of the second adiabatic turbine ($\eta = 0.8$) is 0.01 MPa. Hint: you do not need to find states for all the streams. Solve for the streams as needed.



- (a) (10) Determine the reversible outlet enthalpy for turbine I. Note: if you interpolate using a calculator program, be sure to provide the values plugged in.

- (b) (5) Determine the actual outlet enthalpy from turbine I and work (kJ/kg) produced by turbine I.
- (c) (10) Determine the enthalpies of streams 5, 6, 7.
- (d) (10) Determine the ratio of flowrate ratio, m_2/m_1 .
- (e) (5) Determine the actual entropy for the outlet of turbine I. Note: if you interpolate using a calculator, be sure to provide the values plugged in.

February 24, 2005, OPEN BOOK, CLOSED NOTES

General Instructions

- Submit all problems in the order of the exam.
- Do all work on exam pages. Use back if necessary. Submit all exam pages and the PH chart.
- For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

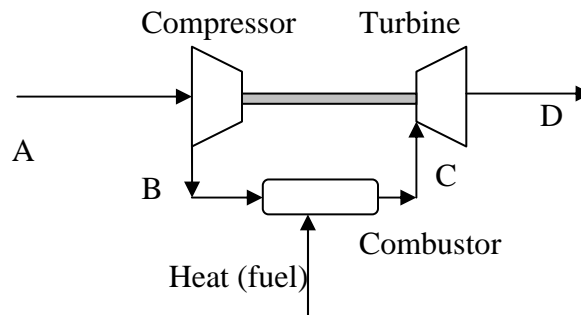
1. Methane (1.6 moles) is compressed in a closed piston/cylinder isothermally. The initial temperature and pressure are 253K and 0.1 MPa. The final pressure is 0.5 MPa. Assume $C_p/R = 4.298$ is independent of temperature.

(a) (5) Determine the work required (kJ).

(b) (5) Determine ΔH and Q .

(c) (5) Determine ΔS (J/K).

2. An ideal gas is used in a gas turbine as shown below. The compressor ($\eta = 0.8$) and the turbine ($\eta = 0.8$) are coupled through a shaft. The gas turbine is to be modeled as a Brayton cycle (ignoring moles of fuel and combustion products). $T_A = 25^\circ\text{C}$, $P_A = P_D = 1$ bar. The pressure at B and C is 7 bar. The temperature at C is 845°C . For the ideal gas, use $C_p = 29.1$ J/mol-K, and assume C_p is independent of T.

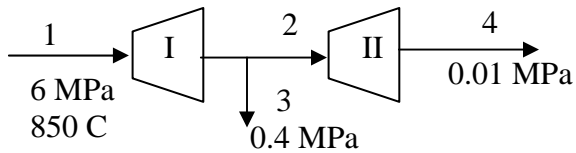


(a) (5) Determine the work required in the compressor (kJ/mol) and the outlet temperature B.

(b) (5) Determine the work produced by the turbine (kJ/mol).

(c) (5) Determine the amount of heat that must be added to the combustor by burning fuel. (kJ/mol).

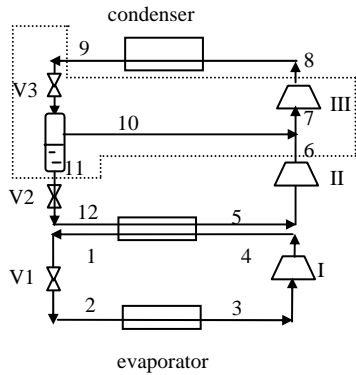
3. Adiabatic steam turbines I and II are each 85% efficient. Determine the work produced in each turbine (kJ/kg). Provide the numbers used for any interpolation.



(a) (15) Determine the outlet state 2 and the work produced by the turbine I.

(b) (10) Determine the outlet state 4 and the work produced by the turbine II.

4. The following cascade cycle uses ethane. The compressors are adiabatic and 75% efficient. The operating fluid is ethane (chart attached). The dotted line is a boundary used in part (e).



	P(MPa)	T(K)	H (kJ/kg)	S(kJ/kg-K)
1				
2	0.5	220		
3	0.5			
4'	1.2			
4	1.2			
5	1	240		
6'				
6				
7				
8	3.5			
8'	3.5			
9				
10	2			
11	2			
12	1			

- (a) (10) Determine the enthalpies for states 9, 11, 1. Label the states on the PH chart.
- (b) (10) Determine the flowrate ratio m_{10}/m_9 .
- (c) (10) Mark states 2 and 3 on the chart. Determine the cooling provided by the evaporator, kJ/kg.
- (d) (10) Mark state 4' on the chart. Determine the work required in compressor I if has a mechanical efficiency of 85%.
- (e) (10) For the dotted boundary, write the energy balance for ethane. Insert all relevant stream numbers into the balance. If heat and work are relevant for the boundary, use intensive Q's and W's. Do not rearrange the balance or combine with other equations.

Ethane chart

February 22, 2004, OPEN BOOK, CLOSED NOTES

General Instructions

- Submit all problems in the order of the exam.
- Do all work on exam pages. Use back if necessary. Submit all exam pages and the PH chart.
- For steam table interpolations, write down the values you use for interpolation even if you use a calculator.
- Avoid writing answers without showing the method. Partial credit cannot be given without documentation of the method.

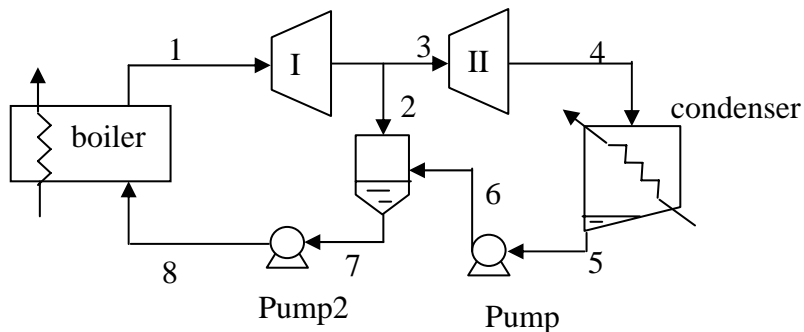
1. An ideal gas flows through a steady-state adiabatic compressor ($\eta = 0.8$). The inlet is 298K and 0.1 MPa. The outlet is 0.4 MPa. The temperature-independent heat capacity is $C_p = 29.1$ J/molK.

(a) (10) Determine the reversible outlet temperature.

(b) (10) Determine the actual outlet temperature.

(c) (5) Determine the size of compressor (kW) necessary to process 150 mol/min.

2. A power plant uses a two stage turbine with a open feedwater preheater as shown below. Steam exits the boiler/superheater at 500°C and 3 MPa. The outlet of the first adiabatic turbine ($\eta = 0.8$) is at 0.3 MPa. The outlet of the second adiabatic turbine ($\eta = 0.8$) is 0.01 MPa. Hint: you do not need to find states for all the streams. Solve for the streams as needed.



- (a) (10) Determine the reversible outlet enthalpy for turbine I. Note: if you interpolate using a calculator program, be sure to provide the values plugged in.
- (b) (5) Determine the actual outlet enthalpy from turbine I and work (kJ/kg) produced by turbine I.
- (c) (10) Determine the enthalpies of streams 5, 6, 7.
- (d) (10) Determine the ratio of flowrate ratio, m_2/m_1 .
- (e) (5) Determine the actual entropy for the outlet of turbine I. Note: if you interpolate using a calculator, be sure to provide the values plugged in.

3. The refrigeration cycle below uses R-500 (PH diagram attached). Stream 1 is saturated vapor at 0.2 MPa and stream 4 is saturated liquid at 0.8 MPa. The compressor is adiabatic ($\eta = 0.85$). Heat exchanger I serves increase the temperature from 1 to 2 and decrease the temperature from 4 to 5. Stream 2 is at 280K and 0.2MPa.

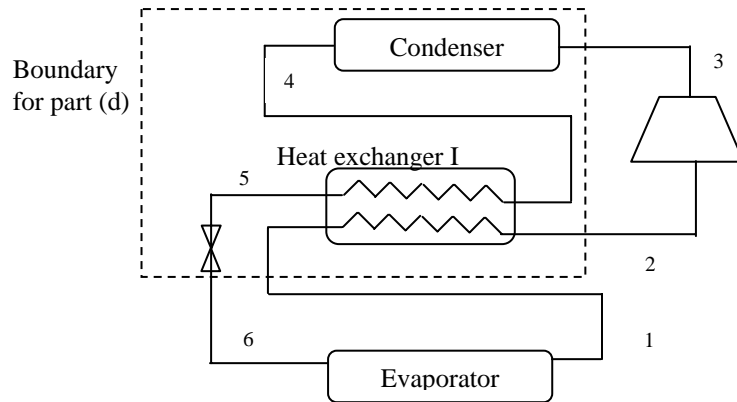


Table is provided for convenience. The problem may not require all values.

Mark your points clearly on the attached chart.

Stream	T(K)	P (MPa)	H(kJ/kg)	S(kJ/kg-K)
1		0.2		
2	280	0.2		
3'				
3				
4		0.8		
5				
6				

(a) (15) Determine the work done by the compressor (kJ/kg).

(b) (5) Determine the enthalpy of stream 5.

(c) (5) Determine the quality of stream 6 and the heat transfer in the evaporator (kJ/kg).
(Note: if you were unable to locate H5 in part (b), assume a value of 80 kJ/kg for this calculation).

(d) (10) For the dotted boundary, write the energy balance for R-500. Insert all relevant stream numbers into the balance. If heat and work are relevant for the boundary, use intensive Q's and W's. Do not rearrange the balance or combine with other equations.

