ME 200 Thermodynamics – Spring 2020
PREPARING FOR EXAM 3

I. University Exam Policy Changes - Spring 2020

The university is recommending that we provide a 24-hour exam period to facilitate asynchronous student access and completion of any exam. Therefore, exam 3 will be delivered via your Blackboard sites and will be a mix of multiple choice and fill in numerical answers. These will be based on problems similar to previous exams, but they will be shorter, you won't be able to show work, and there will be no partial credit.

II. Class Notes, Examples and Quizzes

Review all class notes, examples, quizzes and homework including the material covered in homework problems HW-1 through HW-32**.** Do you understand all of the concepts that were presented and discussed? Can you solve the examples and quizzes without looking at solutions?

III. Homework Problems

Be able to solve all of the homework problems without having to look at the solutions! Note that solutions for the homework problems are posted on the ME 200 website.

IV. Old Exams

The ME 200 website has a previous exam. Try to solve the old exam within a 90-minute window, including all of the require steps that you would employ on the real exam. Note that Exam 3 will be a different format with a mix of multiple choice and fill in numerical answers with no partial credit, but will cover similar topics and concepts.

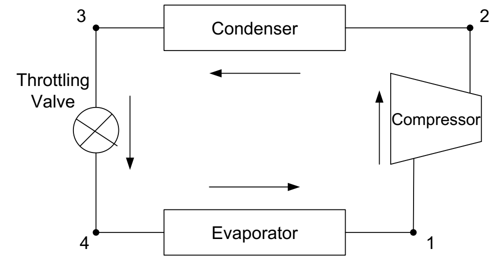
V. Some Additional Practice Problems

Although the following problems are examples of topics covered in Exam 3, it is not comprehensive and the exam will only include problems that are multiple choice and fill in numerical answers with no partial credit.

1. Circle the correct answer for each.
   (a) Entropy of air treated as an ideal gas depends only on temperature. (True or False)
   (b) Enthalpy of air treated as an ideal gas depends only on temperature. (True or False)
   (c) Enthalpy of water treated as an incompressible substance depends only on temperature. (True or False)
   (d) Heat transfer is always zero during an isothermal process. (True or False)
   (e) The entropy change of a substance undergoing an internally reversible process is always zero. (True or False)
   (f) Entropy of a fluid undergoing an adiabatic, steady-state throttling process using a flow restriction (e.g. valve) device (Increases, Decreases, Remains the Same)
   (g) Entropy of water treated as an incompressible substance undergoing an isothermal process (Increases, Decreases, Remains the Same)
   (h) Entropy of a pure substance undergoing a phase change from saturated vapor to saturated liquid at constant pressure (Increases, Decreases, Remains the Same)
   (i) Change in entropy of a fluid having undergone a complete cycle in a reversible Carnot heat engine is (Positive, Negative, Zero)
   (j) Change in entropy of a fluid having undergone a complete cycle in an irreversible heat engine is (Positive, Negative, Zero)
   (k) An ideal gas at high pressure expands through an adiabatic turbine to a lower pressure in a steady-state, steady-flow process. Does the entropy of the gas always increase for an irreversible process (Yes or No)?

(l) An irreversible process can never have a negative entropy change. (True or False)

(m) A designer proposes to replace the throttling valve in a refrigeration cycle by an adiabatic and reversible turbine (producing work) from state 3 to state 4, i.e. state 4 changes. Does the coefficient of performance of the refrigeration cycle decrease, increase or remain the same if states 1, 2, and 3 are not changed (Increase, Decrease, Remain the Same)?



2. You are in charge of selecting Turbine A or Turbine B for a steady state application. The two turbines are adiabatic, use air [R=0.287 kJ/(kgK)] as the working fluid, operate between the same inlet and exit pressures of 1000 kPa and 110 kPa, have the same inlet temperature of 1260 K, and have the same mass flow rate.
   - Turbine B has an isentropic efficiency, $\eta_{TB} = 96.8\ \%$, and an entropy generation per unit mass, $s_{genB} = 0.025\ kJ/(kgK)$.
   - Turbine A operating data is given in the table.

Turbine A Conditions		
States	***T* [K]**	***P* [kPa]**
1 - inlet	1260	1000
2 - exit	750	110

2. 1 If Turbine A has an isentropic efficiency, $\eta_{TA} = 98.0\ \%$,

(a) which of the following is true for the work per unit mass from the turbines.

O $w_{TA} < w_{TB}$ O $w_{TA} > w_{TB}$ O $w_{TA} = w_{TB}$ O cannot determine

(b) which of the following is true for the exit entropy (state 2) of the turbines:

O $s_{TA,2} < s_{TB,2}$ O $s_{TA,2} > s_{TB,2}$ O $s_{TA,2} = s_{TB,2}$ O cannot determine

2.2 Using ideal gas property data in your tables,

(a) Calculate the isentropic efficiency for Turbine A. $\eta_{TA}$is closest to which of the following values.

O $\eta_{TA} = 98.0\%$ O $\eta_{TA} = 96.8\%$ O $\eta_{TA} = 95.0\%$ O $\eta_{TA} = 90.0\%$

(b) Calculate the entropy generation per unit mass for Turbine A. s_{genA} is closest to which of the following values.

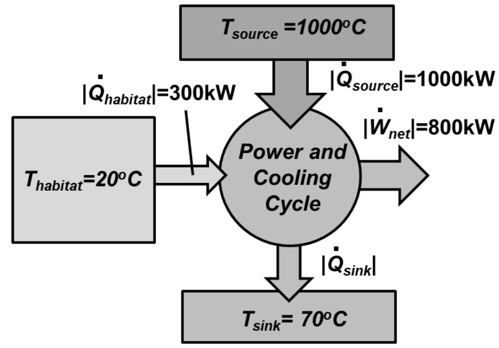
O $s_{genA} = 0.025\ kJ/(kgK)$
O $s_{genA} = 0.05\ kJ/(kgK)$
O $s_{genA} = 0.10\ kJ/(kgK)$
O $s_{genA} = 0.01\ kJ/(kgK)$

(c) Which turbine would you select?

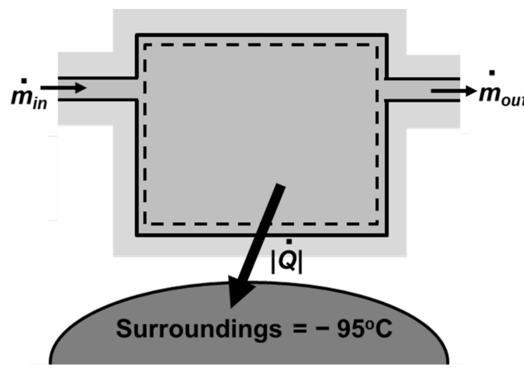
O Turbine A O Turbine B O both are the same O cannot determine

3. A small air conditioner cools a space at 20°C at a rate of 2.5 kW and there is a heat transfer to the outdoors at a temperature 35°C. What is the rate of entropy production for a COP of 5?

4. A NASA engineer has devised a system to be used on the moon for creating both power and cooling for a future human habitat through heat transfer from a solar collector (heat source) at 1000°C and heat transfer to the lunar surface (sink) at 70°C. The system cools the habitat that is at 20°C and is claimed to produce a net power output of 800 kW. Given the heat transfer rates shown on the figure, evaluate whether the net power delivery rate is possible for the given conditions? Justify your answer using an entropy balance with calculations. If it is not possible to deliver the stated power output, then what is the maximum possible power output for the given source and habitat heat transfer rates?

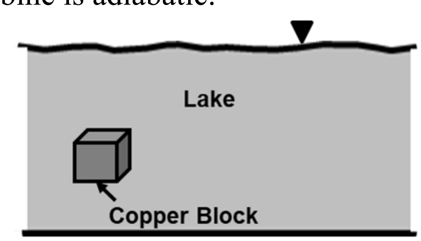


5. An inventor claims to have devised a steady-flow compressor, which requires no shaft-power input. It is claimed that CO_2 at 15 bar and 325 K can be compressed to 20 bar, where it will emerge at 270 K, simply by a heat transfer from this device. The patent application states that the device will handle 2 kg CO_2 per second and is driven by a "cold surroundings" at – 95°C. They further state that the CO_2 enters and leaves the device at very low velocity, and that no significant elevation changes are involved. Can these claims be valid? Assume ideal gas but allow for variable specific heats. Depict the process on a T-s diagram showing constant pressure lines.



6. At steady state, steam with a mass flow rate of 5 kg/s enters a turbine at 400°C and 40 bar and expands to 3 bar. The power developed by the turbine is 2127 kW. The steam then passes through a heat exchanger with a negligible change in pressure, exiting at 400°C. Air enters the heat exchanger in a separate stream at 1.4 bar, 820 K and exits at 1.2 bar, 590 K. Determine the rate of entropy production for the turbine and heat exchanger. Neglect changes in kinetic and potential energy and assume the turbine is adiabatic.

7. A 1 kg piece of copper at 30°C is dropped in a large lake that is at 15°C. Determine the entropy production for the copper block. Assume that the copper has a constant specific heat of 0.39 kJ/(kgK) and treat the lake as a reservoir at constant and uniform temperature.



8. Air enters a nozzle at 4 bar, 550 K, and 60 m/s and exits at 0.75 bar. Assuming ideal gas behavior, variable specific heats and a reversible and adiabatic process, determine the exit temperature of the air.

9. A rigid tank with a volume of 1.0 m^3 initially contains H_2O at 0.07 MPa and 100°C. It is filled from a steam line at 0.70 MPa and 200°C. The tank is filled to a level of 90 % liquid on a volume basis. The tank is maintained at 100°C during the process. Evaluate the required heat transfer (kJ) and entropy generation (kJ/K) for the process.

10. Air flowing steadily at a rate of 5 kg/s enters an adiabatic compressor at 1 bar and 300 K (State 1) and is compressed to a pressure of 6.07 bar (State 2) with a power input of 1170.5 kW. The specific heat is not constant. Molecular weight of air = 28.97 kg/kmol. Do the following: (a) determine the temperature of air at the exit of the compressor, in K; (b) determine the rate of entropy generation for the compressor, in kW/K; (c) determine the power input if the compressor is reversible and adiabatic, in kW; (d) show the isentropic and actual process for air on T-s diagram. Label states and constant pressure lines.

11. A piston-cylinder device contains 0.25 kg of air initially at a temperature of 27°C and absolute pressure of 1 bar (State 1). The air undergoes a compression process, where $PV^{1.3}$ = constant, until the volume is 20% of the initial volume (State 2). The cylinder is fitted with a cooling water jacket all around its outer wall. The cooling water jacket contains 1.75 kg of liquid water. The water is initially at a temperature of 25°C and an absolute pressure of 1 bar (State 3) at the start of the air compression process. Heat transfer occurs only between air in the cylinder and water inside the cooling jacket since the water jacket is perfectly insulated on its outside. Air molecular weight: 28.97 kg/kmol; Liquid water specific heat: 4.18 kJ/kg-K. Determine the following: (a) boundary work (kJ) for air during the compression process; (b) temperature change (°C) of water during the compression process; (c) entropy change (kJ/K) for the air; (d) entropy change (kJ/K) for the water; (e) entropy generation for the entire process (both air and water).