ME 200 Thermodynamics – Spring 2023
PREPARING FOR EXAM 3

I. Class Notes, Examples, and Quizzes

Review all class notes, examples, and quizzes**.** Do you understand all the concepts presented and discussed? Could you solve the examples and quizzes without looking at the solutions?

II. Homework Problems

Be able to solve all the homework problems without having to look at the solutions!

III. Previous Exam

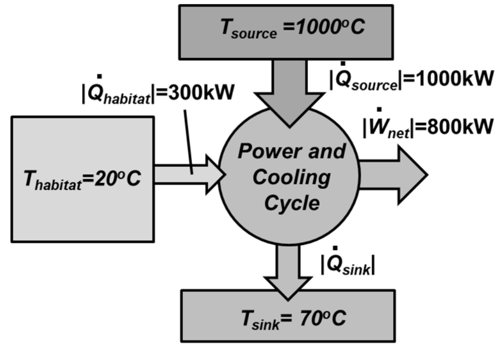
One previous exam has been posted on your Brightspace site or your course site. Try to solve this exam in the time allotted for this 90-minute exam. Note Exam 3 is of 60-minute duration.

IV. Some Additional Practice Problems

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)

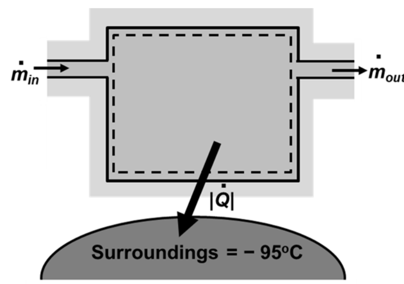
2. A small air conditioner maintains a cooled space at 20°C when the outside temperature is 35°C. The air conditioner removes energy at the rate of 2.5 kW from the cooled space and its COP is 5. Find the rate of entropy production, in kW/K.

3. 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 (heat sink) at 70°C. The system cools the habitat and maintains it at 20°C. The overall system is claimed to produce a net power output of 800 kW. Heat transfer rates for the source and the habitat are shown.



   a) Evaluate whether the net power delivery rate is possible for the given conditions? Justify your answer using an entropy balance with calculations.
   b) If it is not possible to deliver the stated power output for the given heat transfer rates for the source and the habitat, then find the maximum possible power output, in kW.

4. 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 has a mass flow rate of 2 kg/s and is driven by cold surroundings at –95°C. The claim further states 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 behavior but consider variable properties for CO_2. Depict the process on a T-s diagram showing constant pressure lines.

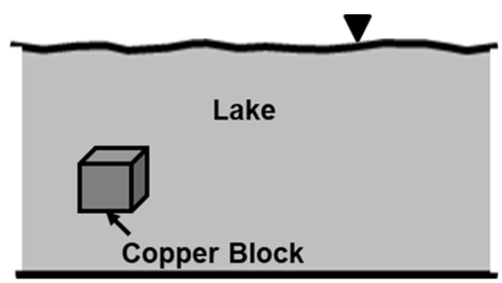


5. Steam with a mass flow rate of 5 kg/s enters an adiabatic turbine operating at steady state at 400°C and 40 bar and expands to 3 bar. The power developed by the turbine is 2127 kW. The steam then passes through a heat exchanger with a negligible change in pressure, exiting at 400°C. Air enters the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

   Find the rate of entropy production for the turbine and the heat exchanger, in kW/K.

6. A 1 kg piece of copper at 30°C is dropped in a large lake that is at 15°C. Assume that copper has a constant specific heat of 0.39 kJ/(kg-K) and treat the lake as a reservoir at constant and uniform temperature.

   Find entropy production for the copper block, in kJ/K.



7. 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 until there is 90% liquid on a volume basis. The tank is maintained at 100°C during the process.

   Calculate the required heat transfer, in MJ, and entropy generation, in kJ/K.

8. Air flowing steadily at the rate of 5 kg/s enters an insulated compressor at 1 bar and 300 K (State 1) and is compressed to a pressure of 6.07 bar (State 2). The compressor requires power input of 1170.5 kW. Consider variable properties for air. MW_{air} = 28.97 kg/kmol.

   a) Determine the temperature of air at the exit of the compressor, in K.
   b) Calculate the rate of entropy generation for the compressor, in kW/K.
   c) Find the power input if the compressor is reversible and adiabatic, in kW.
   d) Determine the isentropic efficiency of the compressor, in %.
   e) Show the isentropic and actual process for air on T-s diagram. Label states and constant pressure lines.

9. Air contained in a closed piston-cylinder device undergoes an irreversible and adiabatic process from an absolute pressure of 900 kPa and an absolute temperature of 500 K (State 1) to an absolute pressure of 300 kPa and an absolute temperature of 400 K (State 2). Air then undergoes a reversible and adiabatic process to an absolute temperature of 800 K (State 3). Consider variable properties for air. MW_{air} = 28.97 kg/kmol.

   a) Find the specific entropy generation during the process from State 1 to 2, in kJ/kg-K.
   b) Determine the isentropic efficiency of the process from State 1 to State 2, in %.
   c) Calculate the absolute pressure of air at State 3, in kPa.

Selected answers are on the next page. Complete solutions will be not provided. You may check your solutions either with instructors or with teaching assistants during office hours.

Selected Answers

2. $\dot{\sigma} = 1.2075 \times 10^{-3} \dfrac{\text{kW}}{\text{K}}$

3. a) Impossible; b) $\dot{W}_{max} = 679.3 \text{ kW}$

4. Possible $\dot{\sigma} = 0.1026 \dfrac{\text{kW}}{\text{K}}$

5. $\dot{\sigma} = 3.279 \dfrac{\text{kW}}{\text{K}}$

6. $\sigma = 5.1193 \times 10^{-4} \dfrac{\text{kJ}}{\text{K}}$

7. $Q = -2092 \text{ MJ}$, $\sigma = 793 \dfrac{\text{kJ}}{\text{K}}$

8. a) $T_2 = 530 \text{ K}$; b) $\dot{\sigma} = 0.302 \dfrac{\text{kW}}{\text{K}}$; c) $\dot{W}_s = -1016 \text{ kW}$; d) $\eta_{compressor} = 86.8\%$

9. a) $\sigma_{12} = +0.0873 \dfrac{\text{kJ}}{\text{kg-K}}$; b) $\eta_{expansion} = 75.3\%$; c) $P_3 = 3764 \text{ kPa}$