Thermodynamics (ME – 111)

Tutorial: Second law of Thermodynamics & Entropy

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1. Heat is transferred to a heat engine from a furnace at a rate of 80 MW. If the rate of waste heat rejection to the nearby river is 50 MW, determine the net power output and thermal efficiency of the engine.

2. An inventor claims to have developed a heat pump producing 200 kW of heating effect for a 293 K heated zone while using only 75 kW of power and a heat source at 273 K. Justify the validity of his claim.

3. The structure of a house is such that it loses heat at a rate of 3800 kJ/h per °C difference between the indoor and outdoor. A heat pump, requiring 4 kW of power input, is used to maintain this house at 24 °C. Determine the lowest outdoor temperature for which this heat pump can meet the heating requirements of this house.

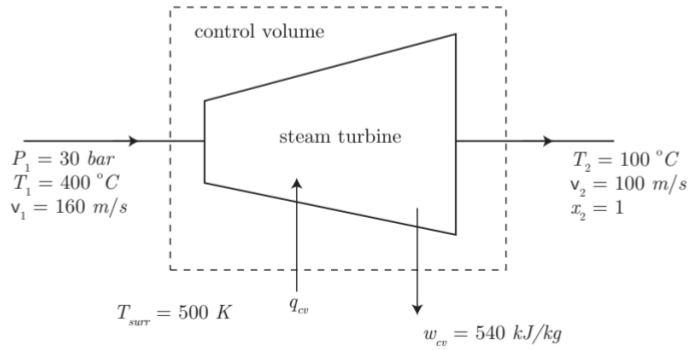
4. Air is expanded from 2000 kPa & 500 °C to 100 kPa & 50 °C. Determine the change in specific entropy of air during the process following both approximate & exact approach, and determine the error incurred on assuming constant specific heats.

5. An isentropic steam turbine receives 2 kg/s of steam at 6 MPa & 500 °C, and leaves at a pressure of 0.3 MPa. Determine the maximum amount of work that can be obtained from this turbine. If the actual exit condition is of saturated vapor, determine the actual work output and isentropic efficiency of the turbine. Plot ideal & actual processes on T-s plane.

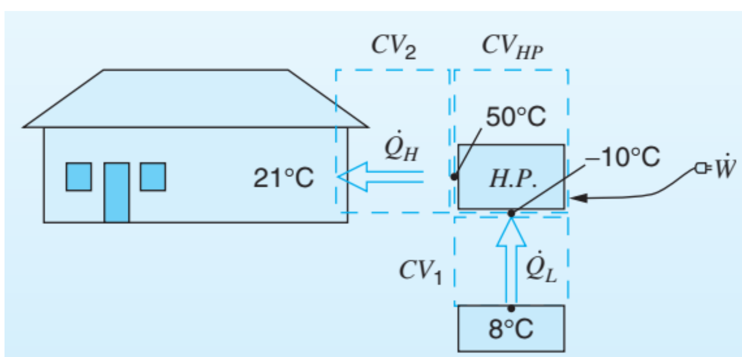
6. Steam enters a steady-flow adiabatic nozzle with low inlet velocity as a saturated vapor at 6 MPa and expands to 1.2 MPa. Assuming an isentropic efficiency of 0.88, calculate the exit velocity of steam.

7. We have m = 10 kg of liquid water at T_1 = 0°C. The water freezes, and its final state is solid water at T_2 = 0°C. Confirm the validity of second law.

8. A steam turbine has an inlet condition of P_1 = 30 bar, T_1 = 400°C, inlet velocity v_1 = 160 m/s. Its exhaust condition is T_2 = 100°C, v_2 = 100 m/s, x_2 = 1. The work for the turbine is w_{cv} = 540 kJ/kg. Find entropy generated per unit mass. The surroundings are at 500 K.



9. Consider a modern air conditioner using R-410a working in heat pump mode, as shown in Figure. It has a COP of 4 with 10 kW of power input. The cold side is buried underground, where it is 8°C, and the hot side is a house kept at 21°C. For simplicity, assume that the cycle has a high temperature of 50°C and a low temperature of −10°C. We would like to know where entropy is generated associated with the heat pump, assuming steady-state operation.



10. Assume an air tank has 40 L of 100 kPa air at ambient temperature 17°C. The adiabatic and reversible compressor is started so that it charges the tank up to a pressure of 1000 kPa and then it shuts off. We want to know how hot the air in the tank gets and the total amount of work required to fill the tank.

11. Derive entropy production in adiabatically filling a rigid tank with an incompressible liquid.

12. Derive entropy production in adiabatically filling a rigid tank with an ideal gas.

13. Steam at 40.0 MPa, 800°C expands through a heated nozzle to 0.100 MPa and 90.0% quality at a rate of 100. kg/h. Neglect the inlet velocity and any change in potential energy, and take the entropy production rate to be 10.0% of the magnitude of the entropy transport rate due to heat transfer. Determine

   a. The entropy production rate if the surface temperature of the nozzle is 450°C.

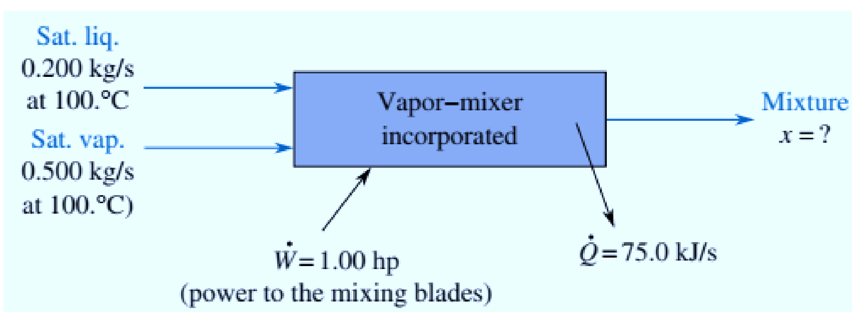
   b. The exit velocity.

   c. The exit area of the nozzle.

14. A new Yo Yo Dyne propulsion system has three flow streams, as shown in Figure. It mixes 0.500 kg/s of saturated water vapor at 100°C with 0.200 kg/s of saturated liquid water at 100°C in a steady flow, steady state, isobaric process. This system is cheaply made and uninsulated; consequently, it loses heat at the rate of 75.0 kJ/s to the surroundings. Assuming the system boundary temperature is isothermal at 100°C, determine

   a. The quality of the outlet mixture.

   b. The entropy production rate of the system.



15. An engineer claims to be able to compress 0.100 kg of water vapor at 200°C and 0.100 MPa in a piston-cylinder arrangement in an isothermal and adiabatic process. The engineer claims that the final volume is 6.10% of the initial volume. Determine

   a. The final temperature and pressure. b. The work required. c. Show whether the process is thermodynamically possible.

16. An insulated tank 1V 5 1.6628 L2 is divided into two equal parts by a thin partition. On the left is an ideal gas at 100 kPa and 500 K; on the right is a vacuum. The partition ruptures with a loud bang.

(a) What is the final temperature in the tank?

(b) What is Dsuniv for the process?