ME 24-221
Thermodynamics I

Final Examination
19 December 2000
Instructor: J. Murthy
Open book, open notes
3 hours
Total: 60 points
Problem 1: 10 points; Problem 2: 10 points; Problem 3: 20 points; Problem 4: 20 points

1. A rigid tank contains air 5 kg of liquid water at 100 kPa and 15°C. A paddle does 500 kJ of work on the water, after which it is found that the water temperature has risen to 60°C. Assume that the surroundings are at 25°C and that the water remains liquid throughout the process.

   (a) Find the heat transfer to the water in kJ.

   (b) Find the entropy change of the water in kJ/K.

   (c) Find the entropy change of the surroundings in kJ/K.

   (d) Hence find the entropy change of the universe in kJ/K.

   (e) Is this process possible? Explain.

2. A heavily insulated piston-cylinder arrangement contains 3 kg of water at 100 kPa and x=0.8. It is compressed in an irreversible process until the pressure reaches 800 kPa. The entropy generation due to irreversibilities is 1.544 kJ/K.

   (a) Write the First and Second Law considering water to be your system.

   (b) Find the final temperature of the system in °K.

   (c) Find the work done on the system in kJ.

3. Air contained in a piston-cylinder assembly undergoes an ideal Stirling cycle, shown in Figure 1. The Stirling cycle consists of the following processes:

   (a) An isothermal compression 1-2.

   (b) A constant volume heat addition 2-3.

   (c) An isothermal expansion 3-4.

   (d) A constant volume heat loss 4-1.

   All processes are reversible. Heat is added to the system in the processes 2-3 and 3-4 and rejected from the system in the processes 4-1 and 1-2.

   For the Stirling cycle under consideration, the pressure and temperature at the beginning of the isothermal compression are 100 kPa, 30°C respectively. The maximum temperature in the cycle is 1200°C. The compression ratio v_1/v_2 is 5. Assuming constant specific heats, find

   (a) The pressures P_2, P_3 and P_4 in kPa.

   (b) The work done in the processes 1-2 and 3-4 in kJ/kg.

   (c) The heat transfer in each of the processes 1-2, 2-3, 3-4 and 4-1 in kJ/kg.

   (d) The thermal efficiency of the cycle.

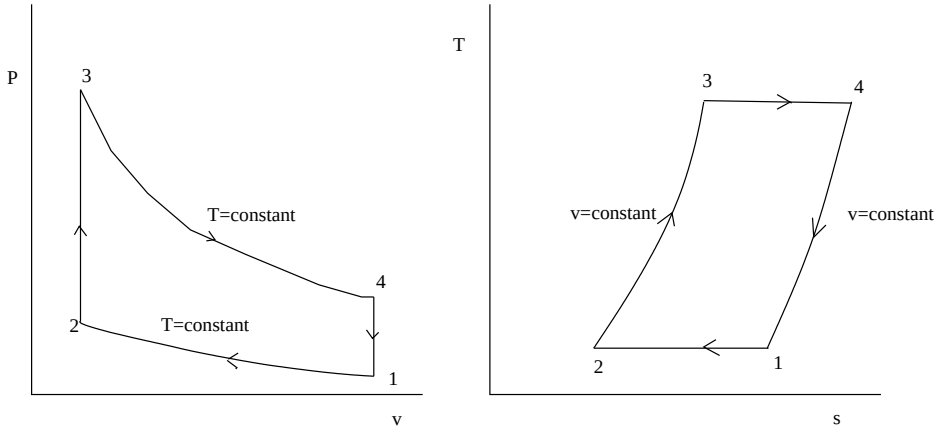

Figure 1: Schematic for Problem 3

4. Consider a variation on the Rankine cycle, as shown in Figure 2. Water is the working substance. Saturated liquid at 10 kPa leaves the condenser in state 1 and is pumped to state 2. Steam leaving the boiler (Boiler 1) is at 5 MPa and 500°C and is expanded in the first turbine stage to a pressure of 200 kPa. It is then passed through a second boiler (Boiler 2) and heated to a temperature of 300°C before being expanded in the second turbine stage.

   Assume that the pump is isentropic, but that each turbine stage has an isentropic efficiency of 85%. Assume the boilers and condenser to be constant pressure devices. Find:

   (a) The work done in each turbine stage in kJ/kg.

   (b) The heat transferred to the water in each of the boilers in kJ/kg.

   (c) The pump work in kJ/kg.

   (d) The thermal efficiency of the cycle.

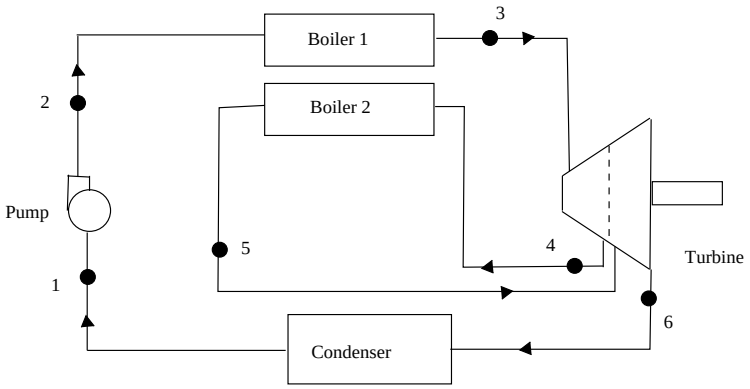

Figure 2: Schematic for Problem 4