University of Toronto
Faculty of Applied Science and Engineering
Final Examination, December 17, 2001
Third Year—Mechanical Engineering
MIE310F – Thermodynamics
Exam Type: C
Examiner: D. Li

****

- Total time allowed: Two and half hours.
- This is a closed book and closed note exam.
- One page Aid Sheet (both sides) and a calculator are allowed.
- The value of each question is given.

****

Q1. A rigid tank containing 0.4 m^3 of air at 400 kPa and 30°C connected by a valve to a piston-cylinder device. Initially the piston sits at the bottom of the cylinder. The mass of the piston is such that a pressure of 200 kPa is required to raise the piston. The valve is now opened slightly, and air is allowed to flow into the cylinder from the bottom until the pressure in the tank drops to 200 kPa. During the process, heat is exchanged with the surroundings such that the entire air remains at 30°C at all time. Assume air as ideal gas with a molecular weight of 28.97 kg/kmol and a constant specific heat C_P = 1.006 kJ/kgK. Determine
A (14) The heat transfer during this process.
B (6) The entropy generation of this process.

Q2. A hair dryer operates by electrical power at a steady state. The air enters the dryer at 22°C and 100 kPa with a speed of 3.7 m/s. The air leaves the dryer through an area of 18.7 cm^2 at 83°C and 110 kPa with a speed of 9.1 m/s. Measurement shows that 0.1 kW of heat is transferred into the surrounding air from the hair dryer's outer surface at a temperature 47°C. Assume air as an ideal gas with a molecular weight of 28.97 kg/kmol and a constant specific heat C_P = 1.006 kJ/kgK.
A (6) Determine the electrical power required to operate the hair dryer, in kW.
B (5) Determine the entropy generation rate of this process.
C (9) The hot air generated by the hair dryer is cooled to 43°C in a heat exchanger by a stream of water (C_P = 4.18 kJ/kgK). The entire heat exchanger operates at 1 atm pressure and water's temperature increases from 20°C to 35°C. Find water's mass flow rate, the rate of heat transfer to water, and the entropy generation rate of this heat exchanger.

Q3. A thermal cycle consists of the following processes:
1—2, polytropic compression, PV^n = const. from state 1 (20°C, 150 kPa and 0.5 m^3) to state 2 (140°C, 400 kPa).
2—3, isentropic compression to state 3 (450 kPa).
3—4, polytropic expansion, following the same PV^n = const. relationship, to state 4 (0.3 m^3).

4—1, isentropic expansion process to state 1.
Helium gas is the working liquid. Assume helium gas as ideal gas, $R = 2.0769$ kJ/kgK, $C_p = 5.1926$ kJ/kgK, $C_v = 3.1156$ kJ/kgK. Determine:

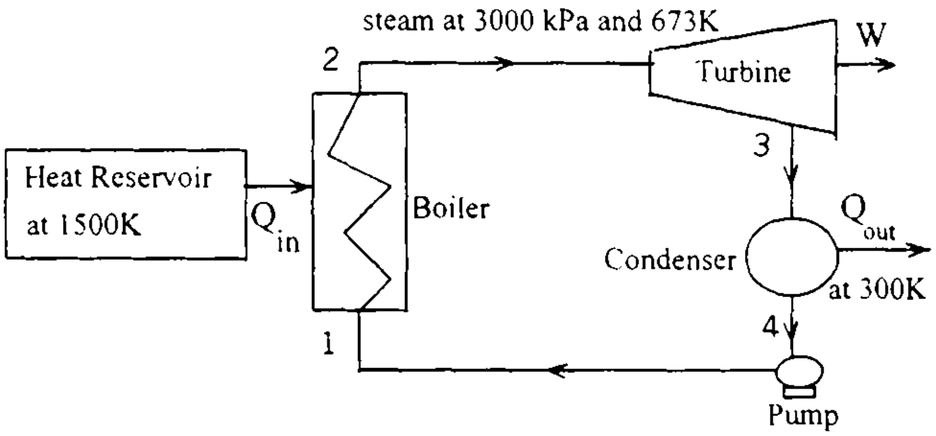
A. (5) Sketch the cycle on a P-V diagram.
B. (8) Heat transfer in process 1—2.
C. (7) Heat transfer in process 3—4.
D. (5) Net work of the cycle
E. (5) The thermal efficiency and the 2nd law efficiency of the cycle. Use the average temperature of the heat supply to the cycle and the environmental temperature $T_0 = 20°C$.

Q4. An inventor claims to invent a device that operates on a cycle. This cycle receives heat from one reservoir and produces a net amount of work.

A. (3) Does the device satisfy the 1st law of thermodynamics? Show the proof of your answer.
B. (7) Does the device satisfy the 2nd law of thermodynamics? Show the proof of your answer.

Q5. For a simple steam power plant (with water as the working liquid) shown below, consider a mass flow rate of 1 kg/s, neglect kinetic energy, potential energy and pump work, find

A. (6) The 1st-law efficiency of the power plant.
B. (3) The 2nd-law efficiency of the power plant, assuming $T_0 = 300$ K.
C. (6) Entropy generation for the power plant.
D. (5) Entropy generations for the boiler, the turbine and the condenser, respectively.



$h_1 = 168.77$ kJ/kg, $h_2 = 3232.5$ kJ/kg, $h_3 = 2334.35$ kJ/kg, $h_4 = 168.77$ kJ/kg
$s_1 = 0.5763$ kJ/kg k, $s_2 = 6.9246$ kJ/kg k, $s_3 = 7.4847$ kJ/kg k, $s_4 = 0.5763$ kJ/kg k.