Qualifying Examination Summer 2022

Thermodynamics

Notes:

- Duration: 2.5 hours.
- Open book (the textbook provided during the exam).
- Calculator is allowed.
- Laptops, cell phones, and similar electronic devices are **not allowed**.
- State your assumptions for each problem.

1. A piston-cylinder assembly contains 1 kg of water, initially occupying a volume of 0.5 m^3 at 1 bar. Energy transfer by heat to the water results in an expansion at constant temperature to a final volume of 1.694 m^3. Kinetic and potential energy effects are negligible. For the water, (a) show the process on a *T*-*v* diagram, (b) evaluate the work, in kJ, and (c) evaluate the heat transfer, in kJ.

(25 points)

2. As shown in Fig. 1, hot industrial waste water at 15 bar, 180°C with a mass flow rate of 5 kg/s enters a flash chamber via a valve. Saturated vapor and saturated liquid streams, each at 4 bar, exit the flash chamber. The saturated vapor enters the turbine and expands to 0.08 bar, x(quality) = 90%. Stray heat transfer and kinetic and potential energy effects are negligible. For operation at steady state, determine the power, in hp, developed by the turbine.

(30 points)

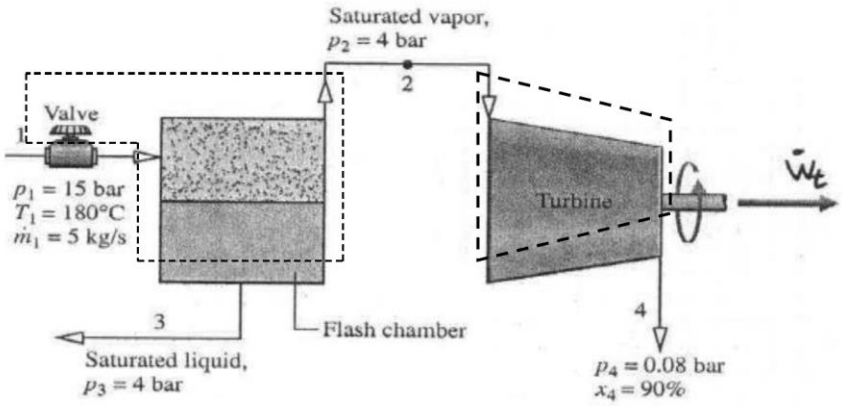

Fig.1

3. By supplying energy at an average rate of 24,000 kJ/h, a heat pump maintains the temperature of a dwelling at 20°C. If electricity costs 8.5 cents per kWh, determine the minimum theoretical operating cost for each day of operation if the heat pump receives energy by heat transfer from
   (a) The outdoor air, at -7°C
   (b) The ground, at 5°C

(20 points)

4. Consider a thermodynamic cycle driven by heat received from a finite-sized body (mass *M*, specific heat *C*) initially heated to temperature T_H and discharging energy by heat transfer to an identical body initially cooled to temperature T_C. Work is produced until the temperatures of the bodies

equilibrate at T_E. Find 1) the minimal theoretical possible value of T_E and 2) the maximum work that can be produced before equilibration. Also determine 3) the minimum work from a refrigeration cycle necessary to restore the system to its initial state (bodies at T_H and T_C).
Hint: consider entropy balance.

(25 points)