ME 354 THERMODYNAMICS - 2

9 February 2004

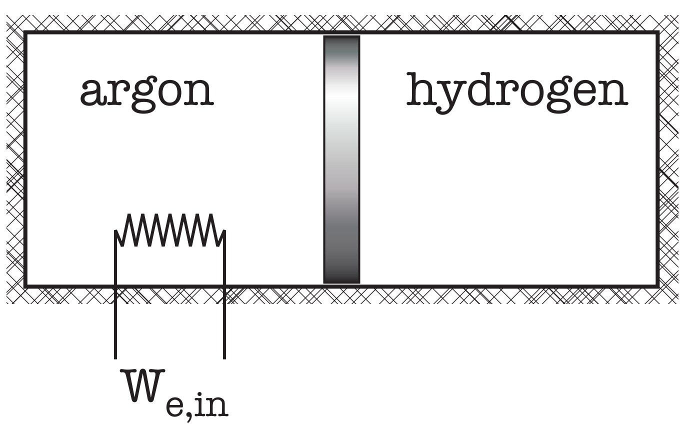
Midterm Examination R. Culham

- This is a two-hour, closed-book examination.
- You are permitted to use one 8.5 in.× 11 in. crib sheet. (one side only) and the Property Tables and Figures from *Thermodynamics: An Engineering Approach*
- There are 3 questions to be answered. Read the questions very carefully.
- Clearly state all assumptions.
- It is your responsibility to write clearly and legibly.

Question 1 (20 marks)

Two well insulated chambers initially have equal volumes of $\mathbf{1\ m^3}$ and contain argon and hydrogen, respectively. The chambers are separated by a frictionless, adiabatic piston. Both gases are initially at $\mathbf{20\ {}^\circ C}$ and $\mathbf{150\ kPa}$. An electrical resistance heater transfers energy to the argon until the pressure of both gases reaches $\mathbf{300\ kPa}$. The hydrogen can be assumed to undergo a reversible process. Assume constant specific heats (@ $\mathbf{300\ K}$) and assume the dead state conditions to be $T_0 = 20\ {}^\circ C$ and $P_0 = 100\ kPa$.

a) Determine the final temperature of the argon in ($\boldsymbol{K}$).
b) Determine the electrical input in ($\boldsymbol{kJ}$).
c) Determine the availability destruction ($\boldsymbol{kJ}$) in the system.



Question 2 (20 marks)

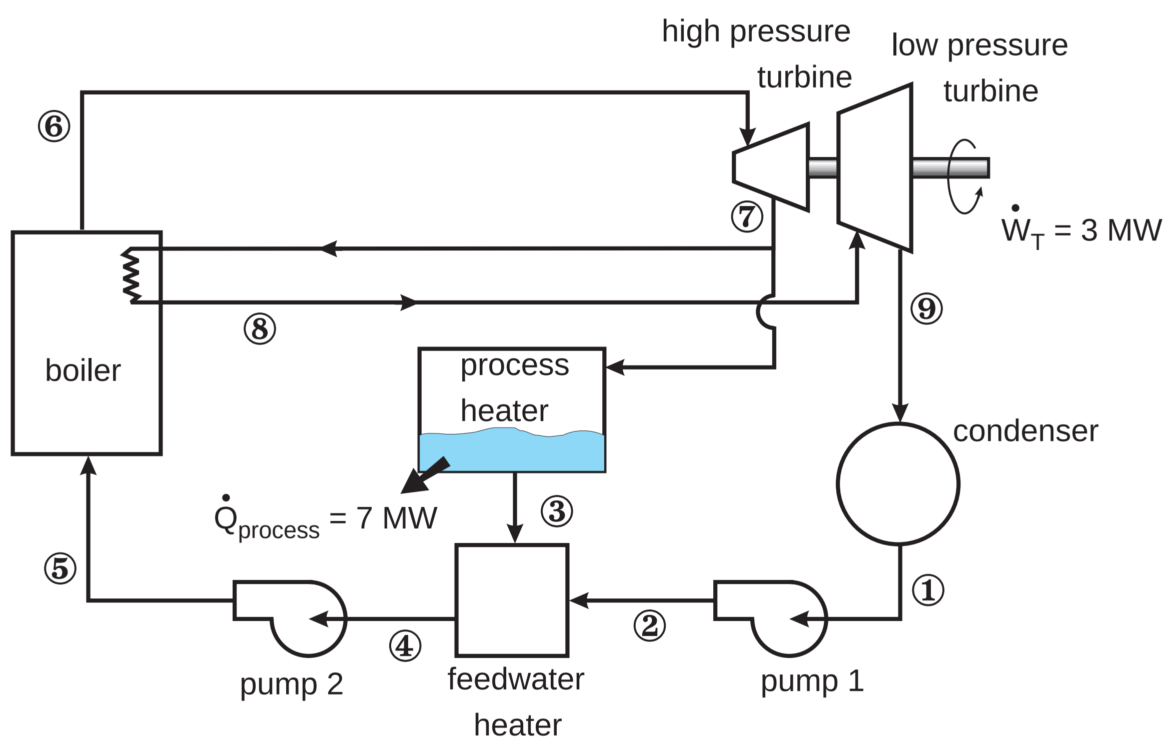
Consider a cogeneration power plant which is modified with reheat and which produces **3** $\boldsymbol{MW}$ of power and supplies **7** $\boldsymbol{MW}$ of process heat. Steam enters the high-pressure turbine at **8** $\boldsymbol{MPa}$ and **500** $\boldsymbol{°C}$ and expands to a pressure of **1** $\boldsymbol{MPa}$**.** At this pressure, part of the steam is extracted from the turbine and routed to the process heater, while the remainder is reheated to **500** $\boldsymbol{°C}$ and expanded in the low-pressure turbine to the condenser pressure of **15** $\boldsymbol{kPa}$. The condensate from the condenser is pumped to **1** $\boldsymbol{MPa}$ and is mixed with the extracted steam, which leaves the process heater as a subcooled liquid at **120** $\boldsymbol{°C}$. The mixture is then pumped to the boiler pressure.

Assume:

1. both turbines are isentropic
2. perfect mixing in the feedwater heater
3. constant specific heats
4. no internal irreversibilies
5. neglect pump work in your calculations

Find:

a) draw the complete process on a $\boldsymbol{T - s}$ diagram and clearly label all state points
b) determine the rate of heat input in the boiler, [$\boldsymbol{MW}$]
c) determine the mass fraction of steam extracted for process heating.



Question 3 (20 marks)

A vapor compression refrigerator using R-134a is to provide chilled water at $\mathbf{5\ °C}$. Originally the water is at $\mathbf{20\ °C}$. The pressure in the evaporator is $\mathbf{280\ kPa}$ and in the condenser $\mathbf{700\ kPa}$. The R-134a enters the compressor at $\mathbf{0\ °C}$ and leaves at $\mathbf{50\ °C}$. The work transfer rate to the adiabatic, compressor is $\mathbf{750\ W}$. The R-134a leaves the condenser as a saturated liquid. Assume the dead state to be $\mathbf{100\ kPa}$ and $\mathbf{20\ °C}$.

a) Determine the COP of the refrigerator.
b) Determine the mass flow rate $[\boldsymbol{kg/hr}]$ of the chilled water that can be produced at the prescribed temperature.
c) Determine the rate of availability destruction $[\boldsymbol{W}]$ in the compressor and the expansion valve.
d) Determine the second law efficiency of the cycle. Explain why in some instances the second law efficiency in a refrigeration cycle can appear to be negative.