University of Waterloo

ME 354

THERMODYNAMICS 2
MIDTERM EXAMINATION

February 14, 2011 5:30 pm - 7:30 pm

Instructor: R. Culham

Name: ____________________

Student ID Number: ____________________

Instructions

1. This is a 2 hour, closed-book examination.
2. Answer all questions in the space provided. If additional space is required, use the back of the pages or the blank pages included.
3. Permitted aids include:
   - Property Tables Booklet (Fundamentals of Thermodynamics, Borgnakke and Sonntag, 7th ed) or a photocopy of this booklet
   - one 8.5 in. × 11 in. crib sheet. (one side only)
   - calculator
4. It is your responsibility to write clearly and legibly. Clearly state all assumptions. Part marks will be given for part answers, provided that your methodology is clear.

Question	**Marks**	**Grade**
1	17	
2	20	
3	18	
TOTAL	55	

Question 1 (17 marks)

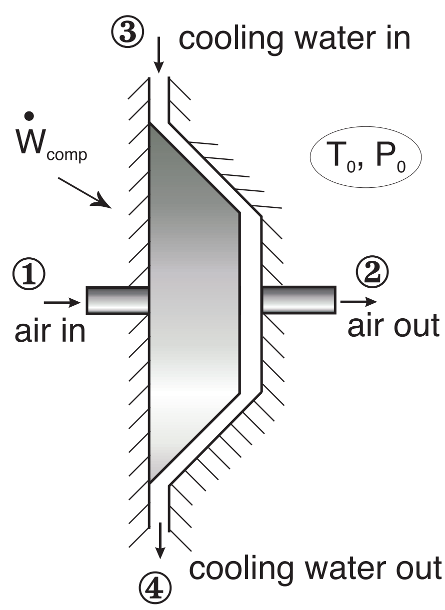
A compressor fitted with a water jacket and operating at steady state conditions takes in air with a volumetric flow rate of $\mathbf{900}\ \boldsymbol{m^3/h}$ at $\mathbf{300}\ \boldsymbol{K}$ and $\mathbf{95}\ \boldsymbol{kPa}$ and discharges air at $\mathbf{590}\ \boldsymbol{K}$ and $\mathbf{800}\ \boldsymbol{kPa}$. Cooling water enters the water jacket at $\mathbf{20}\ \boldsymbol{°C}$, $\mathbf{100}\ \boldsymbol{kPa}$ with a mass flow rate of $\mathbf{1400}\ \boldsymbol{kg/h}$ and exits at $\mathbf{30}\ \boldsymbol{°C}$ and essentially the same pressure. There is no significant heat transfer from the outer surface of the water jacket to its surroundings and kinetic and potential energy effects can be ignored. Properties can be assumed to be constant with respect to temperature. The dead state is assumed to be $\boldsymbol{T_0} = \mathbf{25}\ \boldsymbol{°C}$ and $\boldsymbol{P_0} = \mathbf{1}\ \boldsymbol{atm}$.

a) Determine the rate of exergy input $[\boldsymbol{kW}]$ into the system.

b) Determine the change in flow exergy rate $[\boldsymbol{kW}]$ for the air stream.

c) Determine the change in flow exergy rate $[\boldsymbol{kW}]$ for the water stream.

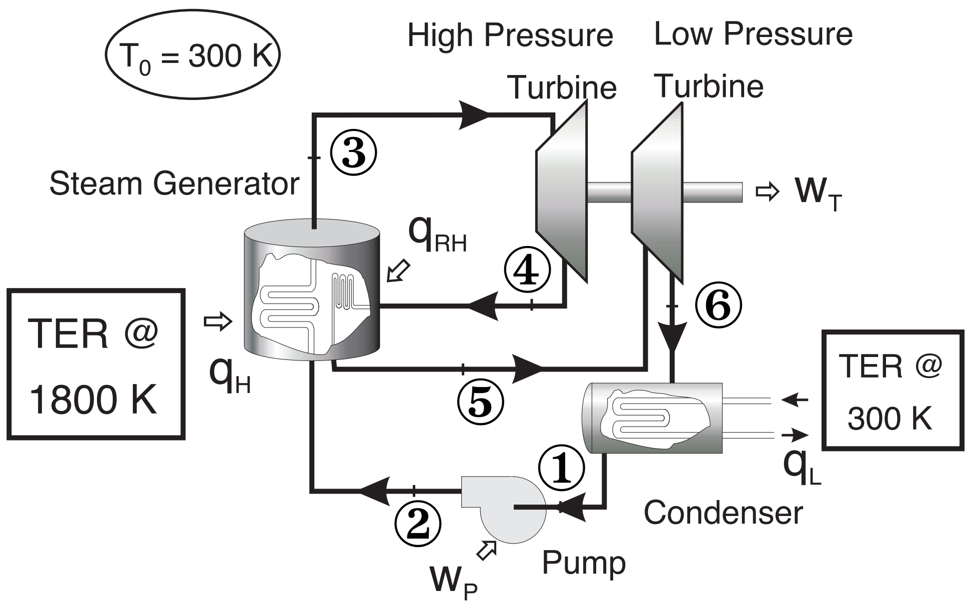
d) Determine the rate of exergy destruction $[\boldsymbol{kW}]$ in the process.



Question 2 (20 marks)

A steam power plant operates as an ideal reheat Rankine cycle. Steam enters the high pressure turbine at **8** $\boldsymbol{MPa}$ and **500** °$\boldsymbol{C}$ and leaves at **3** $\boldsymbol{MPa}$. Steam is then reheated at a constant pressure to **500** °$\boldsymbol{C}$ before it expands to **20** $\boldsymbol{kPa}$ in the low pressure turbine. Assume that heat is being added to the boiler from a high temperature source at **1800** $\boldsymbol{K}$ and the condenser is transferring heat to a temperature sink at **300** $\boldsymbol{K}$. Determine:

a) the total work output of the turbines, $[\boldsymbol{kJ/kg}]$
b) the thermal efficiency of the cycle
c) the entropy generation at each of the heat transfer devices, $[\boldsymbol{kJ/(kg \cdot K)}]$



Question 3 (18 marks)

A vapor compression refrigerator using R-134a as the working fluid requires **500 *W*** of electrical power to drive the isentropic compressor. Both the evaporator and the condenser are assumed to be 100% effective, that is to say the low temperature TER and the saturated vapor leaving the evaporator are both at $-5\ °C$ and the high temperature TER and the saturated liquid leaving the condenser are at $40\ °C$. The dead state is assumed to be $T_0 = 25\ °C$ and $P_0 = 1\ atm$. Determine:

a) the rate of heat transfer in the evaporator and the condenser, [***kJ/kg***]
b) the COP of the cycle
c) the change in availability in the cold temperature space and the high temperature space [***kJ/kg***]
d) the second law efficiency for the refrigerator
e) the total cycle exergy destruction, [***kW***]