

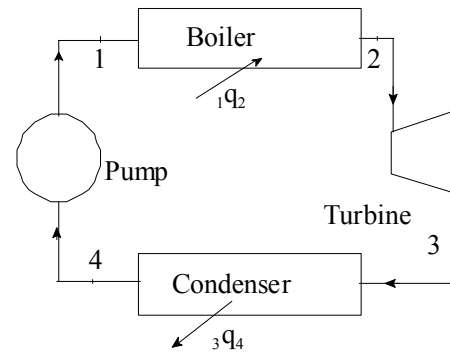
MCG 2130 - THERMODYNAMICS I

Final Exam
10 December 2007
Prof. R.E. Milane

Duration: 3 hours
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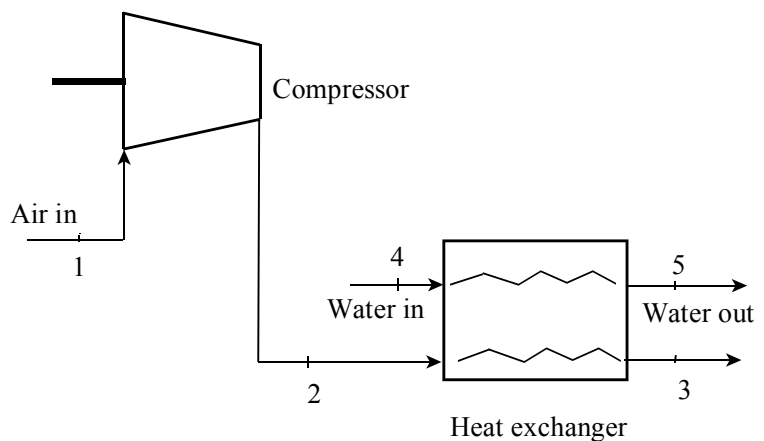
Closed book. Non programmable calculators only are allowed. Steam tables are supplied. Data and equations are provided at the end of this paper.

1. (5 marks) (a) Write down the expression for the inequality of Clausius. Explain briefly.
(b) The schematic shows a power plant operating with water. The pressure in the boiler is constant and equals to 0.15 MPa with qualities $x_1 = 0\%$ and $x_2 = 100\%$. The pressure in the condenser is constant and equals to 20 kPa with qualities $x_3 = 100\%$ and $x_4 = 0\%$. The processes in the turbine and in the pump are adiabatic. Determine whether the cycle is possible or reversible or impossible. Explain briefly.



2. (5 marks) Water is compressed in an isothermal and reversible steady state process. Initially the pressure is $P_1 = 0.6$ MPa and the temperature is $T_1 = 180$ EC; the final state is saturated vapor with quality $x_1 = 1.0$. The mass flow rate is $m = 0.5$ kg/s. Calculate the heat transfer and the work done in kJ.

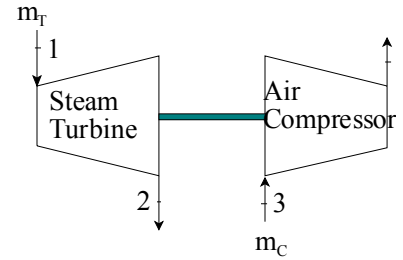
3. (12 marks) Air flows through the compressor and heat exchanger as shown on the schematic. Air enters a compressor at $P_1 = 96$ kPa and $T_1 = 27$ EC at a volume flow rate of $VF_1 = 0.45$ m³/s; air exits the compressor at $P_2 = 230$ kPa and $T_2 = 127$ EC. Then air is cooled through the heat exchanger to $T_3 = 77$ EC using cooling water. The water temperatures at the inlet of the heat exchanger is $T_4 = 25$ EC and at the outlet $T_5 = 40$ EC. Find



- a) the mass flow rate of air and the compressor power in kW,

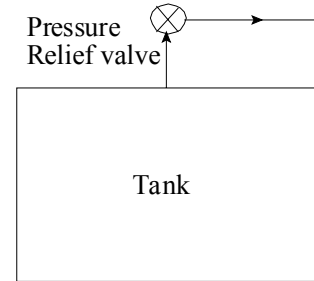
- b) the mass flow rate of water,
 c) the isentropic efficiency of the compressor.

4. (13 marks) The schematic shows a steam turbine with an isentropic efficiency of 70% that drives an air compressor with an isentropic efficiency of 78%. Steam at $P_1 = 2 \text{ MPa}$ and $T_1 = 350 \text{ EC}$ enters the turbine and exits at $P_2 = 10 \text{ kPa}$ with a mass flow rate m_T . Air at $P_3 = 0.1 \text{ MPa}$ and $T_3 = 27 \text{ EC}$ enters the compressor and exits at $P_4 = 0.5 \text{ MPa}$ with a mass flow rate $m_C = 0.1 \text{ kg/s}$. Assuming that both the turbine and the compressor are adiabatic, calculate



- a) the work required by the compressor in kJ per kg of mass flow rate in compressor,
 b) the work provided by the turbine in kJ per kg of mass flow rate in turbine,
 c) the mass flow rate in the turbine m_T .

5. (15 marks) A rigid tank having a volume of 1.0 m^3 contains water initially at 130 EC , with 40% liquid and 60% vapor, **by volume**. A pressure relief valve on the top of the tank is set to 1.2 MPa , that is when the pressure in the tank reaches 1.2 MPa , the water will be discharged in such a way that the pressure in the tank remains at 1.2 MPa . The water is heated from its initial condition using a heat source at 400 EC until the tank contains saturated water ($x=100\%$) at 1.2 MPa . Calculate:



- a) the initial quality,
 b) the heat transfer during this process,
 c) the net entropy change. Does this process violate the second law?

Expressions and data for air

$$s_2 - s_1 = C_{p0} \ln(T_2/T_1) - R \ln(P_2/P_1)$$

$$T_2/T_1 = (P_2/P_1)^{(k-1)/k} = (v_1/v_2)^{k-1}$$

$C_{p0} \text{ air} = 1.0035 \text{ kJ/kg.K}$
 $C_{v0} \text{ air} = 0.716 \text{ kJ/kg.K}$
 $R \text{ air} = 0.287 \text{ kJ/kg K}$
 $k \text{ air} = 1.4$

Total marks for this paper: 50