Université d'Ottawa
Faculté de génie

Département de
Génie Mécanique

uOttawa
L'Université canadienne
Canada's university

University of Ottawa
Faculty of Engineering

Department of
Mechanical Engineering

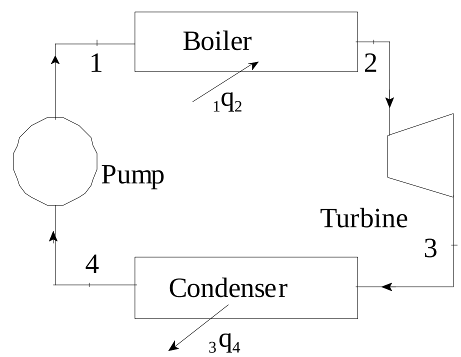
MCG 2130 - THERMODYNAMICS I

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

Duration: 3 hours

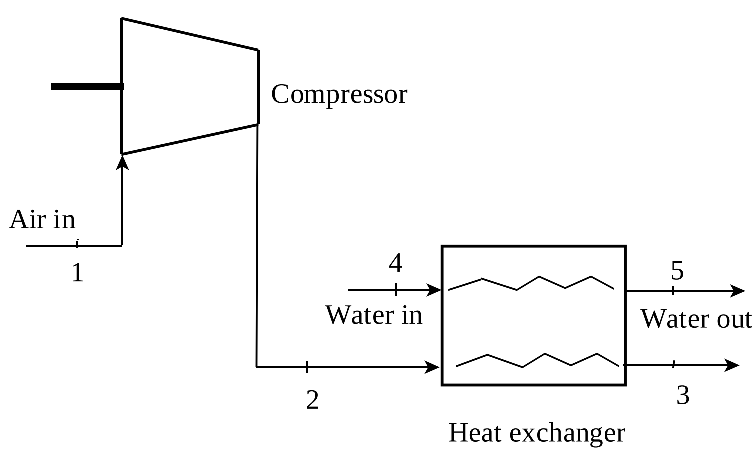
Closed book. Non programmable calculators only are allowed. Steam tables are supplied. Data and equations are provided at the end of this paper.

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.



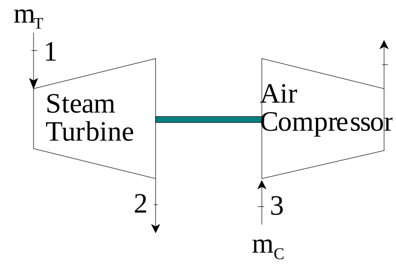
2. (5 marks) Water is compressed in an isothermal and reversible steady state process. Initially the pressure is P_1 = 0.6 MPa and the temperature is T_1 = 180 EC; the final state is saturated vapor with quality x_l = 1.0. The mass flow rate is m = 0.5 kg/s. Calculate the heat transfer and the work done 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 m^3/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 = 25EC and at the outlet T_5 = 40 EC. Find
a) the mass flow rate of air and the compressor power in kW,



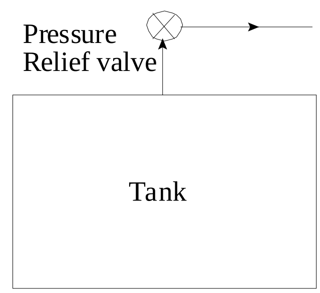
b) the mass flow rate of water,
c) the isentropic efficiency of the compressor.

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 MPa and T_1 = 350 EC enters the turbine and exits at P_2 = 10 kPa with a mass flow rate m_T. Air at P_3 = 0.1 MPa and T_3 = 27 EC enters the compressor and exits at P_4 = 0.5 MPa with a mass flow rate m_C = 0.1 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

$s_2 - s_1 = Cp_0 \ln (T_2/T_1) - R \ln (P_2/P_1)$
$T_2/T_1 = (P_2 / P_1)^{(k-1)/k} = (v1/v2)^{k-1}$
Cp_0 air = 1.0035 kJ/kg.K
Cv_0 air = 0.716 kJ/kg.K
R air = 0.287 kJ/kg K
k air =1.4

Total marks for this paper: 50