Student Code Number:_____

Ph.D. Qualifying Exam

Thermodynamics

Spring 2011

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Directions: Open Book (only one book allowed) and closed notes

Answer all six questions

All questions have equal weight

Time: 3.0 hours

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- Take any required property from your book, approximate values if necessary
- If you make any assumptions to reach a solution, state it clearly

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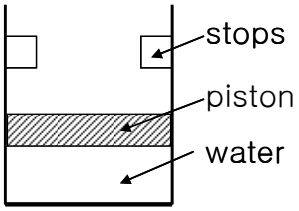
Problem 1: A rigid tank is filled with water (H_2O) which is at 75 ^{0}C. The tank is 2.5 m^3 in volume and the weight of the water is 15 kg. The rigid tank is then slowly heated until it is entirely vaporized.

a) The very moment it is entirely vaporized, what is the temperature of the water?
b) Plot the process (showing the initial and final states) on a T,v plot and on a T,s plot.
c) Is this a fully reversible process? Explain the reason.

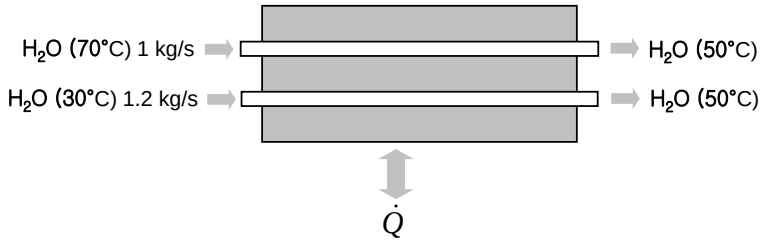
Problem 2: A frictionless piston cylinder mechanism with stops contains 10kg of saturated liquid water at 100kPa. It then undergoes the following two processes.



<u>Process 1</u>: Heat is transferred to the water causing the piston to rise and just touch the stops. At the end of process 1, the quality of the water is $x=0.85$.
<u>Process 2</u>: Heat is further transferred to the water until the pressure reached 300kPa

a) How much heat (Q) is required for process 1?
b) What is the temperature after process 1?
c) What is the temperature after process 2?
d) Draw Process 1 and 2 on a P-v plot.

Problem 3. There is a heat exchanger which operates between two liquid water pipes. Water enters the heat exchanger at 70°C (1kg/s) and 30°C (1.2kg/s). You can add or subtract extra heat (Q) to the heat exchanger. Water exits both pipes of the heat exchanger at 50°C.



a) What is the amount of $\dot{Q}$ required, and which direction is it (in or out)?
b) If the rate heat transfer from a pipe inside the heat exchanger is 2kJ/s·cm, how long does the heat exchanger have to be?
c) Is the overall system reversible or irreversible? Explain.

Problem 4. Air initially having V_1= 0.5m^3, p_1=1bar and T_1=20^{0}C undergoes an internally reversible compression according to $pV^{1.3}$=constant to a final state where T_2=200^{0}C. Assuming air is ideal gas, Determine:

a) the final pressure

b) the work transfer in Kilo Joules

c) the heat transfer in Kilo Joules

d) the entropy change in KJ/Kg.K

e) sketch the process on a P-V and T-S diagrams

Assume the fluid is air with: C_p=1.005 KJ/(kg K), C_v=0.718 KJ/(kg K), R =0.287 KJ/(kg K) and (ratio of specific heat) γ = 1.4

Problem 5. An insulated turbine operates with air, having an entry condition of 960 Kelvin and 0.65 MPa and an exit condition of 600 Kelvin and 0.1 MPa. Neglecting KE & PE changes and assuming the gas is ideal, Determine:

a) the work developed by the turbine per unit mass of air flow
b) whether the expansion process is internally reversible, irreversible or impossible
c) Sketch the T-S diagram for the process, and
d) the maximum possible work to be developed by this turbine

Assume the fluid is air with: C_p=1.005 KJ/(kg K), C_v=0.718 KJ/(kg K), R =0.287 KJ/(kg K) and (ratio of specific heat) γ = 1.4

Problem 6. Steam at 6000 kPa and 500°C enters a steady-flow turbine. The steam expands in the turbine while doing work until the pressure is 1000 kPa. When the pressure is 1000 kPa, 10 percent of the steam is removed from the turbine for other uses. The remaining 90 percent of the steam continues to expand through the turbine while doing work and leaves the turbine at 10 kPa. The entire expansion process by the steam through the turbine is reversible and adiabatic.

a) Sketch the process on a T-s diagram with respect to the saturation lines. Be sure to label the data states and the lines of constant pressure.
b) If the turbine has an isentropic efficiency of 85 percent, what is the work done by the steam as it flows through the turbine per unit mass of steam flowing into the turbine, in kJ/kg?