College of Engineering
Department of Mechanical Engineering

M E 417 Thermodynamics II

Final Examination

December 2002, D.J. Bergstrom

TIME: 3 hours

Provide complete answers to the following questions. State the major assumptions. Where applicable, sketch the process diagram and identify the state points. Reference all property tables that are used.

You are permitted to refer to the property tables in the appendices of the text, the conversion tables on the inside front cover, and your own assignment problem solutions. A generic version of a formula sheet is also attached.

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1. [20 marks] Consider an air standard Stirling cycle with a compression ratio of eight. Recall that for a Stirling cycle, the compression and expansion strokes are isothermal, and a regenerator uses the heat rejected at constant volume to supply the heat added at constant volume. At the beginning of the compression stroke, the temperature, pressure and volume are $290\ K$, $1\,bar$ and $0.03\,m^3$, respectively, and the maximum temperature in the cycle is $900\ K$.

   a) Sketch the process on a $p-\upsilon$ plot.
   b) Calculate the net work developed by the cycle.
   c) Calculate the thermal efficiency.
   d) Is it possible to improve the thermal efficiency of this cycle? Explain.

2. [35 marks] Methane gas at 25^oC, 1 atm enters a reactor operating at steady state and burns with 80 % of theoretical (dry) air entering at 227^oC, 1 atm. An equilibrium mixture of $CO_2, CO, H_2O(g), H_2$ and N_2 exits at 1427^oC, 1 atm. [Enthalpy information for H_2 is provided in an attached table.]

   a) Determine the composition of the exiting mixture per *kmol* of fuel.
   b) Calculate the heat transfer in kJ per *kmol* of fuel.
   c) If the air entered with a relative humidity of 75 %, calculate the kmoles of water brought in by the air per *kmol* of fuel.
   d) Comment on the effect of increasing the exit pressure on the amount of H_2 in the equilibrium mixture. Justify your answer.

3. [25 marks] Air flows through a converging-diverging nozzle between two large reservoirs. The pressure and temperature in the upstream reservoir are: $p = 300\ kPa$ and $T = 100^oC$. The area at the throat and exit plane of the nozzle are $A_t = 10\ cm^2$ and $A_e = 30\ cm^2$, respectively. For air, assume constant specific heats with $k = 1.4$. Assume that the nozzle is choked.

   a) Calculate the pressure at the throat.
   b) Calculate the pressure at the inlet to the downstream reservoir in *kPa* assuming subsonic flow in the diffuser.
   c) Calculate the pressure at the inlet to the downstream reservoir in *kPa* assuming a normal shock wave is located at the exit of the nozzle.
   d) For case c), determine the critical area downstream of the normal shock wave.

4. [20 marks] Consider an air compressor with a pressure ratio of 8. The inlet temperature and pressure is 300 *K* and 1 *bar*, respectively. Let $T_o = 25^oC$, $p_o = 1 bar$, and assume air standard behaviour.

   a) Calculate the temperature at the exit of the compressor for an isentropic efficiency of 80 %.
   b) Give the definition of exergy.
   c) Calculate the change in specific flow exergy across the compressor.
   d) In general, is all of the 'work' (power) supplied to a compressor converted to flow exergy? Justify your answer, but no calculation is required.

Assume insulated compressor.

THE END