COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
M E 417 Thermodynamics II
Final Examination
December 2001; *D.J. Bergstrom*

TIME: 3 hours

Provide specific and complete answers to the following questions. State the major assumptions. Identify the state points, and use a process diagram where appropriate. Reference all tables which are used. This is a closed book exam; the student is only allowed to use the property tables in the text, and can refer to his/her assignment solutions. A generic formula sheet is attached to the exam.

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35 1. Carbon (C) at $25°C$ enters a reactor operating at steady state and burns with oxygen entering at$127°C$, 1 atm. The entering streams have equal molar flow rates. An equilibrium mixture of CO_2, CO and O_2 exits at $2727°C$ and 1 atm. Determine the following per kmol of carbon:

a) The composition of the exiting mixture.

b) The heat transfer between the reactor and its surroundings in kJ.

In addition, for part c), comment on the effect of increasing the exit pressure on the equilibrium composition of CO.

25 2. Air enters the diffuser of a jet engine at 40 kPa, 240 K and with a velocity of $V = 180\ m/s$. The mass flow rate is $\dot{m} = 45\ kg/s$. The compressor efficiency is 85 percent, and it has a pressure ratio of 10. Use an air standard analysis to answer the following questions, and let $R = 0.287\ kJ/kg \cdot K$. Include a sketch of the overall compression process on a $T - s$ diagram.

a) Calculate the temperature and pressure at the exit of the compressor.

b) Calculate the entropy change across the compressor.

c) Evaluate the second-law (exergetic) efficiency for the compressor. Let $T_o = 25°C$ and $p_o = 1\ atm$.

25 3. Air enters a converging-diverging nozzle at a Mach number of 1.2. A normal shock wave stands at the inlet to the nozzle, and the nozzle is choked. The air exits the nozzle at $p = 7\ bars$ and $T = 300°C$ with negligible velocity. The mass flow rate is 45 kg/s. Assume the air to behave as an ideal gas with $k = 1.4$ and $R = 0.287\,kJ/kg \cdot K$. Determine the following information:

a) The stagnation temperature and pressure downstream of the shock wave.

b) The pressure p_y immediately downstream of the shock wave.

c) The area at the inlet.

15 4. Briefly answer the following questions:

a) Use entropy to explain why (following the second law) an engine producing finite work while executing a power cycle cannot receive energy as heat transfer from a single heat reservoir.

b) Give a *definition* of exergy.

c) Based on engineering thermodynamic principles, suggest how the true 'cost' of energy should be determined. Justify your answer.

The End

MERRY CHRISTMAS