COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
M E 417 Thermodynamics II
Final Examination
December 2000: *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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40 1. Air enters the compressor of a gas turbine at 100 $kPa, 300\ K$ with a volumetric flow rate of 5 m^3/s. The air is compressed in two stages to 1200 kPa, with intercooling to 300 K between the stages at a pressure of 350 kPa. The turbine inlet temperature is 1400 K. The compressor and turbine efficiencies are 87 and 85 percent, respectively. Use an air standard analysis to answer the following questions. Include a sketch of the complete cycle on a $T-s$ diagram.

a) Calculate the thermal efficiency.

b) Calculate the back-work ratio.

c) Evaluate the second-law efficiency for the first stage compressor and explain the meaning of this parameter. Let $T_o = 25°C$ and $p_o = 1\,atm$.

d) Describe what is meant by *regeneration*, and discuss whether the possibility for regeneration exists in the present cycle configuration. Justify your answer.

25 2. A normal shock wave stands in a converging-diverging nozzle with a throat area of $A_t = 0.0004\ m^2$. The nozzle draws air from a reservoir at $p = 800\ kPa$ and $T = 300\ K$. If the shock wave is located at a location where $A = 0.0009\ m^2$, calculate the following intensive parameters. Assume the gas to be modelled is air, with $k = 1.4$ and $R = 0.287\ kJ/kg \cdot K$.

a) The pressure, p_x, immediately upstream of the shock wave.

b) The temperature at the exit where $A_e = 0.0015\ m^2$.

25 3. Acetylene gas (C_2H_2) at $25°C$ and $1\,atm$ enters a reactor operating at steady state and burns with 40 percent excess air entering at the same temperature and pressure. An equilibrium mixture of CO_2, H_2O, O_2, NO and N_2 exits at $2200\,K$ and $0.9\,atm$.

a) Write the balanced reaction equation for dry air and complete combustion.

b) If the air has 80 percent relative humidity, calculate the kmoles of water (per kmole of fuel) entering with the air stream.

c) Determine the equilibrium composition of the exiting mixture, again on the basis of one kmole of fuel.

10 4. Determine the enthalpy of combustion for gaseous butane (C_4H_{10}) in kJ per $kmol$ of fuel at $25°C$ and $1\,atm$ assuming water vapour in the products.

The End