ME 417.3 Thermodynamics II
Department of Mechanical Engineering
University of Saskatchewan
Final Examination
9:00am December 13, 2004

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1. A gas-turbine power plant operates with a two-stage compressor, a two-stage turbine, and a regenerator. The pressure ratio across each stage of compression and expansion is three. Both turbine inlets are at 1800 K and both compressor inlets are at 300 K. The regenerator effectiveness is 75%, both compressor stages have an isentropic efficiency of 85%, and both turbine stages have an isentropic efficiency of 90%. Sketch the cycle on a $T - s$ diagram. Calculate the thermal efficiency of the cycle and the back work ratio. Use an air-standard analysis.

2. A converging-diverging nozzle is supplied by a plenum chamber where $P_o = 600\,\text{kPa}$. The throat diameter is 1 cm and the exit diameter is 2 cm. The static temperature at the throat is 250 K. If a normal shock is observed at a diameter of 1.5 cm, what is the pressure in the region where the nozzle discharges? Assume $k = 1.4$.

3. A converging nozzle supplies a long, adiabatic pipe which discharges to a region where $P = 100\,\text{kPa}$. The pressure at the entrance of the pipe is 288 kPa and the pressure at the exit of the pipe is 193 kPa. Find the new pressures at the inlet and exit of the pipe if the pressure in the plenum chamber supplying the converging nozzle is changed to 133 kPa. Assume $k = 1.4$.

4. A 4-cm diameter, frictionless, heated duct is connected to the exit of a converging-diverging nozzle. The converging-diverging nozzle has a design Mach number of 2. Heat is added in the heated duct at a rate of 386.1 kJ/kg. In the plenum chamber supplying the converging-diverging nozzle, $T_o = 300\,\text{K}$ and $P_o = 1\,\text{MPa}$. The duct discharges to a vacuum. Calculate the static pressure at the exit of the heated duct. Assume a constant $c_P = 1.007\,\text{kJ/(kg} \cdot \text{K)}$ and $k = 1.4$.

5. Gaseous propane (C_3H_8) at 25^{o}C and 1 atm enters a well-insulated reactor, and reacts with air that enters the reactor at 400 K and 1 atm. What percentage of theoretical air is used in this combustion reaction if the temperature of the products of combustion is 1200 K? Assume that the effects of kinetic and potential energy are negligible.

6. An air-standard dual cycle has a compression ratio of 9. At the beginning of compression, $p_1 = 100\,\text{kPa}$ and $T_1 = 300\,\text{K}$. The heat addition per unit mass of air is 1400 kJ/kg, with 40 percent added at constant volume and 60 percent added at constant pressure.

   (a) Sketch the cycle on a $p - v$ diagram.

   (b) Calculate the pressure at the end of the constant volume combustion process.

   (c) Calculate the cutoff ratio r_c.

   (d) Use a sketch on a $p - v$ diagram to explain so called *blowdown losses*.