GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2002

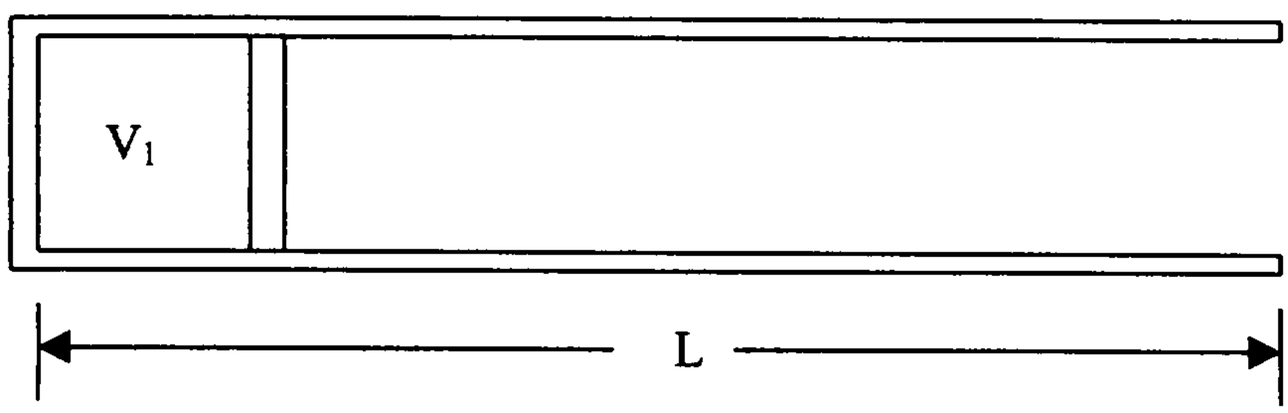
Thermodynamics

EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

1. A gun barrel is used to accelerate a projectile using high pressure air. It can be modeled as a horizontal frictionless piston/cylinder as shown below. It initially contains air at 1380 K, 15 MPa. The cylinder volume at state one is V_1=10 cm^3, and the area of the piston is A_{cyl}=5 cm^2 . The piston, with mass, m_p, is initially held in place by a pin at state 1. The piston is then released. The cylinder is well insulated. The designer wants the pressure inside the barrel to be 200 kPa just before the piston exits the end of the barrel. What should he make the length, L, of the barrel?



2. One of our alumni (GT/ME) spent most of his career in turbine development work. He is now retired and has established a business building specialty turbine-generator systems for under developed countries where the fuel must be bio materials wood, vegetation, animal manure, etc). The system is designed to operate with H2O as the working fluid in a Rankine cycle with a reheat between the low pressure turbine and the high pressure turbine. The lowest pressure in the cycle is about atmospheric and the maximum pressure 10 MPa. The condenser operates at one atmosphere and the steam exiting the low pressure turbine has a quality of 95%. The steam leaving the exit of the high pressure turbine should be slightly superheated to avoid erosion of the blades by condensation droplets so you can assume it is just saturated vapor.

   a. Draw a schematic of the cycle showing all the components and number to significant states numerically starting with "1" between the condenser and the pump with numbers increasing in the direction of flow for the working fluid.
   b. Draw p-v and T-s diagrams for the above system using the same state numbering scheme. Draw on the same diagrams both the ideal Rankine cycle with solid lines and (with broken lines) how you would expect the real system to deviate from the ideal Rankine.

   c. Estimate the best possible cycle efficiency, the electrical energy output per unit of thermal energy input.

   d. Write a paragraph that we might give to the developer of suggestions of what he could do to increase the useful output of the system.

3. An air-standard, ideal Brayton cycle has a pressure ratio of 15. The minimum and maximum temperatures of the cycle are 300 K and 1000 K. The pressure at the inlet to the compressor is 150 kPa.

   a) Determine the pressure and temperature of the air at the beginning of the four processes that make up the cycle.

   b) Calculate the net work and the heat transfer to the air during the combustion process, both for a unit mass of working fluid.

   c) For constant temperature heat source and sinks with T_H = 1000 K and T_L = T_0 = 280 K, is the cycle irreversible? If so, determine the irreversibility per unit mass of each process. If not, explain why.