GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 1999

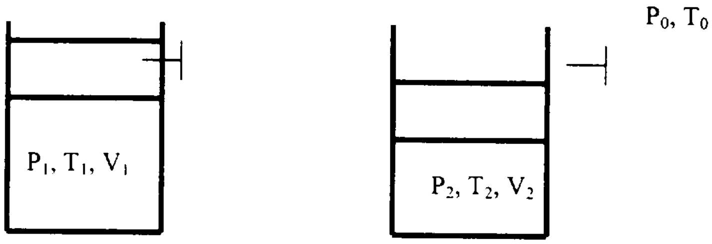
Thermodynamics
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

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

1. Dry saturated steam enters a steady-flow system with a flow rate of 5 lbm/s and a pressure of 80 psia. It proceeds along a reversible isothermal path and leaves the device at 20 psia. Calculate the heat-transfer rate and power developed during the process. Use the first and second laws. Give the power in horsepower.

2. The illustrated cylinder containing 1 kg of air with a friction free piston is a closed system. The cylinder cross section area is 0.1 m^2, and the piston has a mass of 1000 kg. Initially the piston is restrained by a pin, and the air in the piston is at 100 kPa and 300 K. The ambient atmosphere is at 300 K and 100 kPa. Assume that the piston and cylinder are adiabatic. The pin is released, and the piston falls to its equilibrium position.



(1) Find the following properties:

initial volume __________ m^2,

final volume __________ m^2, final pressure __________ kPa, final temperature __________ K

Also find the change in entropy for the air __________ kJ/K

(2) Since the piston and cylinder are adiabatic, explain how the change in entropy can come about.

(3) Assume that the piston-cylinder and a relatively large region of the surroundings can be assumed to be an isolated system. Under this assumption, does this process illustrate any general principle related to entropy?

3. Two kg of H_2O is initially at a saturated vapor state at T_1 = 100 °C (state 1). It undergoes a constant-volume process until the pressure reaches P_2 = 200 kPa (state 2). The H_2O is then compressed along a constant-pressure path until it becomes saturated liquid (state 3).

(a) Draw the process on a *T-v* diagram and a *P-v* diagram, including on each diagram the liquid-vapor saturation curve as well as an isotherm and an isobar through each of the three states. Indicate the values of temperature and pressure at the respective isotherms and isobars.

(b) Determine the changes in internal energy U_3 - U_1 (in kJ) and in temperature T_3 - T_1 (in °C). Given the locations of states 1 and 3, do your answers depend on the internal energy, volume, or temperature at state 2? Why (or why not)?

4. Consider the simple air-standard refrigeration cycle shown below. Air enters the compressor from a building at 0.1 MPa and 25C, and leaves at 0.5 MPa. Air enters the expander at 0.5 MPa and 30C and exits the expander back into the building.

Determine:

1. The coefficient of performance (COP) for this cycle, i.e., $COP=Q_{cooling}/W_{comp}$

2. The rate at which air must enter the compressor in order to provide one kW of cooling.