G. W. Woodruff School of Mechanical Engineering
Ph.D. Qualifying Exam, Spring 2004
Thermodynamics

Problem 1.

A frictionless piston-cylinder assembly contains 3.30 kg of H_2O. Initially the H_2O is in the form of ice at 0°C. The piston has negligible mass. The H_2O is heated slowly until its temperature reaches 120°C. Find the amount of heat transfer. Please indicate the relevant assumptions that you make.

[Recall that the heat of fusion of H_2O is 333.6 kJ/kg.]

Problem 2.

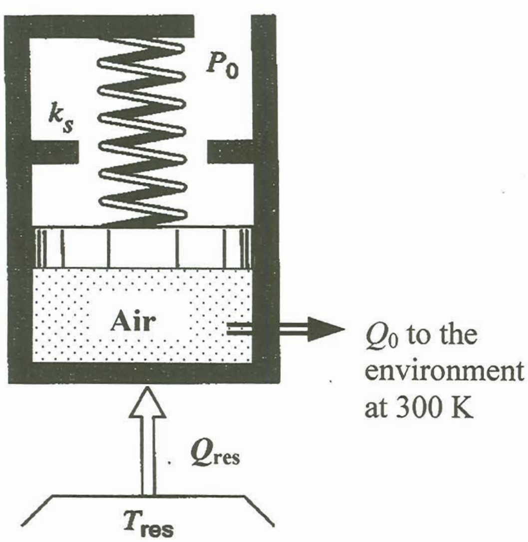
Air in a cylinder with a linear spring/piston arrangement is shown in the figure, where k_s is the spring constant and P_0 the atmosphere pressure. Initially the air is at 200 kPa and 300 K with a volume of 0.5 m^3. If the piston is at the stops, the volume inside will be 1 m^3 and a pressure of at least 400 kPa is required to sustain the piston. In a process, the air is heated from the initial temperature to 1500 K by receiving energy from a thermal reservoir (as shown) at a temperature T_{res} = 1500 K. Assume the piston movement is frictionless, and due to imperfect insulation, the amount of heat loss to the environment (at 300 K) is Q_0 = 240 kJ.

(a) Find the amount of energy that must be taken from the reservoir, Q_{res}.

(b) Determine the amount of total entropy generation.

(c) Comment on the causes of entropy generation.

[Hint: Use Table A-22 *Ideal Gas Properties of Air*.]



Problem 3.

Air flowing at 200 kg/s is used in a combined gas turbine-vapor power plant. Air enters the compressor at 100 kPa, 300 K, and is compressed to 1200 kPa. It enters the gas turbine at 1200 kPa and 1400 K, and expands to 100 kPa. It then flows through a heat exchanger, generating steam, and finally being discharged at 480 K. The steam generated in this heat exchanger enters the turbine as a saturated vapor at 8 MPa, and expands to a condenser pressure of 8 kPa. After condensing to a saturated liquid, it is pumped back to the interconnecting heat exchanger to complete the cycle. All compression and expansion processes are isentropic. You may neglect the power required to pump the condensed water in the vapor cycle described above.

Clearly identify all state points with appropriate diagrams and determine the following:

a) The net work (MW) generated in the gas turbine cycle;
b) The mass flow rate of water in the vapor power cycle;
c) The net work generated (MW) in the vapor power cycle; and
d) The efficiency of this combined cycle power plant.

Properties of steam and air may be obtained from the property tables.