Ph.D. Qualifying Examination

Thermodynamics

Fall 2009

Logistics Notes:

a) Time allowed: 2 hours.
b) Five problems are given. Choose and solve four. If you attempt to solve all five, the score will be given for best four out of five. Problems count 25 points each (total=100 points).
c) Exam is open-book and open-notes (one book and one notebook allowed)
d) State your assumptions, methods, and procedures.
e) Calculators are allowed.
f) Laptops and cell phones are not allowed.

Problem 1.
Ammonia flows through a Y-junction in a duct (one circular cross-section inlet, two outlets). The known conditions at the inlet and outlets 1 and 2 are as follows:

	Inlet	Outlet 1	Outlet 2
Phase state		Saturated vapor	Saturated liquid
Temperature	301K		
Flow rate (mass or vol.)	1 kg/s	2.072 m3/min	
Pressure	1.4 MPa	400 kPa	400 kPa

Find:

a. Volumetric flow rate at outlet 2.
b. Minimum inlet diameter for the ammonia average flow velocity at the inlet not to exceed 15 m/s.

Problem 2.
Quenching is a common process employed to prepare ceramic samples. By rapidly cooling them, high temperature microstructural features can be "frozen" and studied at room temperature. As part of his job as a research assistant, a ME graduate student removes a 250 g ceramic pellet, initially at 1475 K, from a furnace and quenches it by immersing it in a close tank containing 10 Kg of water initially at 275 K.
Each substance can be modeled as incompressible and heat transfer from the tank contents considered negligible.
If the constant specific heat value for water is C_w = 4.211 KJ/Kg K and the ceramic is C_c = 0.85 KJ/Kg K , Determine:

a. Final equilibrium temperature of the ceramic pellet and the water in K.
b. The amount of entropy produced.

Problem 3.
Conditions at the inlet and exit of a water steam turbine are as follows:

	Inlet	Exit
Phase state		Saturated vapor
Pressure	3 MPa	
Velocity	160 m/s	100 m/s
Temperature	673K	373K

The turbine loses 30 kJ per kg of steam flow to its surroundings (average surface temperature 400K).
Find (per kg of steam flow):

a. Work developed by the turbine.
b. Entropy produced.
c. Entropy produced under the assumption that the turbine loses heat at the same rate, but to large surroundings at ambient temperature 300K. Explain why the values for b. and c. are different.

Problem 4.
Air (initially at atmospheric pressure) is contained in a closed rigid tank fitted with a paddle wheel. The paddle wheel stirs the gas, with the power supplied to the wheel at 8W. Assuming the tank is well-insulated, find:

a. Specific volume of the air in the tank after the wheel has been rotating for thirty minutes.
b. Energy transfer to the gas during thirty minutes of wheel rotation.
c. Change in the specific internal energy of the air.

Problem 5
10 kg of H_20 undergo a thermodynamic cycle comprised of four processes:
1-2. Isothermal compression from 5 bar pressure and T=433K (heat transfer $Q_{1\text{-}2}$=-815 KJ)
2-3. Heating at constant volume to 10 bar (at this point, the system reaches a saturated-vapor state)
3-4. Expansion at constant pressure (10 bar)
4-1. Cooling at constant volume.
Assume kinetic and potential energy effects to be negligible. Sketch the cycle in T-v and p-v coordinates. Determine:

a. Net work for the cycle.
b. Thermodynamic efficiency of the cycle.
c. Heat transfer for each process.