Time spent on problems:

Problem 1:

Problem 2:

Problem 3:

Problem 4:

Problem 5:

Problem 6:

16.050 Thermal Energy

Problem Set #4 – Fall 2002

Do all problems. Please use a separate sheet of paper for each problem.

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1. A quantity of air undergoes a thermodynamic cycle consisting of three processes in series.

   Process 1-2: constant-volume heating from P_1= 0.1 MPa, T_1= 15°C, V_1= 0.02 m^3 to P_2= 0.42 MPa

   Process 2-3: constant-pressure cooling

   Process 3-1: isothermal heating to the initial state

   Employing the ideal gas model with c_P=1 kJ/kgK, evaluate the change in entropy for each process. Sketch the cycle on *P-v* coordinates.

2. A liquid system whose mass is *m* kg at temperature *T* was formed by adiabatically bringing together two equal masses of the liquid; initially, one mass was at T_1 and the other at T_2. Derive the entropy production for the system. Prove that the entropy production for the system must be positive. Assume that the liquid has a specific heat of c_p.

3. A closed system consists of an ideal gas with constant specific heat ratio *k*.

   a) The gas undergoes a process in which temperature increases from T_1 to T_2. Show that the entropy change for the process is greater if the change in state occurs at constant pressure than if it occurs at constant volume. Sketch the processes on *P-v* and *T-s* coordinates.

   b) The gas undergoes a process in which pressure increases from P_1 to P_2. Show that the ratio of the entropy change for an isothermal process to the entropy change for a constant-volume process is (1-*k*). Sketch the processes on *P-v* and *T-s* coordinates.

4. Moran and Shapiro, Fundamentals of Engineering Thermodynamics. Problem 6.6, pp. 245.

5. Assume 1 kg of helium undergoes a cycle as follows: heat added 1-2 isobarically from 60°C to 225°C, irreversible adiabatic expansion 2-3 to 25°C during which Δs =0.013 kJ/kgK, heat rejection 3-4 isothermally at 25°C until s_4=s_1; then the cycle is completed with an adiabatic and reversible process 4-1. Determine (**a**) $\oint dQ/T$, (**b**) the entropy change due to internal irreversibility and Δs for the cycle, (**c**) the entropy production for the universe if the source and sink temperatures are each constant and are 225°C, 60°C, respectively.

6. A compressor operates reversibly and isothermally. The fluid medium is an ideal gas with constant specific heats and the kinetic energy at the inlet and outlet station can be neglected. The stagnation pressure ratio (Pt_{exit}/Pt_{inlet}) is Pr.

   a) What is the entropy change of the fluid, inlet to exit, per unit mass?

   b) What amount of heat transfer per unit mass flow rate must occur? Indicate whether the heat transfer is to or from the compressor.

   c) What is the shaft work per unit mass flow rate?