HOMEWORK 5

Handed out: Monday, 24 September 2007
Due: Monday, 1 October 2007 by 5 pm

Notes:

1. Drop HW off in the designated homework box in Upson 123
2. Be sure that you **indicate your recitation section (and your name!)** on the top of the first page of your HW. **We will not accept late homework**.
3. Homework will be returned in your recitation. The TAs have been instructed to keep your HW **for only one extra week** in case you miss a recitation.
4. Problems with (*) refer to problems to be discussed in your recitation. We strongly advice you to try to solve these problems before you attend your recitation. Note that you should submit solutions to ALL problems in this HW including those indicated with a (*).

Problem 1 (Carnot Cycle): One kilogram of air as an ideal gas executes a Carnot power cycle having a thermal efficiency of 60%. The heat transfer to the air during the isothermal expansion is 40KJ. At the end of the isothermal expansion, the pressure is 5.6 bar and the volume is $0.3m^3$ .Determine

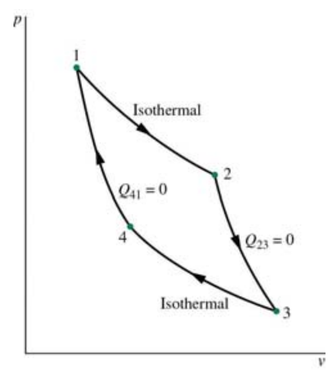
(a) The maximum and minimum temperatures for the cycle, in K.
(b) The pressure and volume at the beginning of the isothermal expansion in bar and m^3, respectively.
(c) The work and heat transfer for each of the four processes in KJ.
(d) Sketch the cycle on p-v coordinates.

Problem 2 (Carnot Cycle): : The pressure-volume diagram of a Carnot power cycle executed by an ideal gas with constant specific heat ratio of k is shown here. Repeating calculations done in class show that

(a) $V_4V_2 = V_1V_3$

(b) $$\frac{T_2}{T_3} = \left(\frac{V_3}{V_2}\right)^{k-1}$$

(c) $$\frac{T_2}{T_3} = \left(\frac{p_2}{p_3}\right)^{\frac{k-1}{k}}$$



Problem 3 (Irreversible processes): A system undergoing a thermodynamic cycle receives Q_H at temperature T'_H and discharges Q_C at temperature T'_C. There are no other heat transfers

(a) Show that the net work developed per cycle is given by

$$W_{cycle} = Q_H\left(1 - \frac{T'_C}{T'_H}\right) - T'_C\,\sigma$$

where σ is the amount of entropy produced owing to the irreversibilities within the system.

(b) If the heat transfers Q_H and Q_C are with hot and cold reservoirs, respectively, what is the relationship of T'_H to the temperature of the hot reservoir and T_H and the relationship of T'_C to the temperature of the cold reservoir T_C?

(c) Obtain an expression for W_{cycle} if there are (i) no internal irreversibilities, (ii) no internal or external irreversibilities.

Problem 4 (Compute entropy increase): A cylindrical rod of length L insulated on its lateral surface is initially in contact at one end with a wall at temperature T_H and at the other end with a wall at a lower temperature T_C. The temperature within the rod initially varies linearly with position z according to $T(z) = T_H - (\frac{T_H - T_C}{L})z$. The rod is then insulated on its ends and eventually comes to a final equilibrium state where the temperature is T_f. Evaluate T_f in terms of T_H and T_C and show that the amount of entropy produced is

$$\sigma = mc\left(1 + \ln T_f + \frac{T_C}{T_H - T_C}\ln T_C - \frac{T_H}{T_H - T_C}\ln T_H\right)$$

where c is the specific heat of the rod.

Problem 5 (*): At steady state, an insulated mixing chamber receives two liquid streams of the same substance at temperatures T_1 and T_2 and mass flow rates $\dot{m}_1$ and $\dot{m}_2$, respectively. A single stream exits at T_3 and $\dot{m}_3$. Using an incompressible substance model with constant specific heat c, obtain an expression for

(a) T_3 in terms of T_1, T_2, and the ratio of mass flow rates $\dot{m}_1 / \dot{m}_3$.

(b) the rate of entropy production per unit of mass exiting the chamber in terms of c, T_1,/T_2, and $\dot{m}_1 / \dot{m}_3$.

Problem 6 (Use tables): Employing the ideal gas model determine the change in specific entropy between the indicated states, in kJ/(kg K). Solve two ways: Use the appropriate ideal gas table, and a constant specific heat value from Table A-20.

(a) air, $p_1 = 100kPa, T_1 = 20^oC, p_2 = 100kPa, T_2 = 100^oC$

(b) air, $p_1 = 1bar, T_1 = 27^oC, p_2 = 3bar, T_2 = 377^oC$

(c) carbon dioxide, $p_1 = 150kPa, T_1 = 30^oC, p_2 = 300kPa, T_2 = 300^oC$

(d) carbon monoxide, $T_1 = 300K, v_1 = 1.1m^3/kg, T_2 = 500K, v_2 = 0.75m^3/kg$

(e) nitrogen, $p_1 = 2MPa, T_1 = 800K, p_2 = 1MPa, T_2 = 300K$

Problem 7 (Reversible process): One kilogram of water initially at 160 ^{o}C, 1.5 bar undergoes an isothermal, internally reversible compression process to the saturated liquid state. Determine the work and heat transfer, in each in kJ. Sketch the process on p-v and T-s coordinates. Associate the work and heat transfer with areas on these diagrams.

Problem 8 (Entropy change): For each of the following systems, specify whether the entropy change during the indicated process is positive, negative, zero, or indeterminate.

(a) One kilogram of water vapor undergoing an adiabatic compression process
(b) Two pounds mass of nitrogen heated in an internally reversible process
(c) One kilogram of Refrigerant 134a undergoing an adiabatic process during which it is stirred by a paddle wheel.
(d) One-pound mass of carbon dioxide cooled isothermally.
(e) Two pounds mass of oxygen modeled as an ideal gas undergoing a constant pressure process to a higher temperature
(f) Two kilograms of argon modeled as an ideal gas undergoing an isothermal process to a lower pressure.