ME 18b, HW 1

Due Tuesday April 8, 2008 (by 5 pm)

Please indicate the number of classes attended and the number of hours spent on homework.

Reading:

Chapter 11 in Sonntag, Borgnakke & Van Wylen. For more information: **Gas Turbine Theory**, by Cohen, Rogers & Saravanamuttoo, which is in Sherman Fairchild Library.

1.1 Thermal efficiency and net work for a Brayton cycle.

In class, we started to derive an expression for the thermal efficiency, η_t, for a closed Brayton cycle as a function of the compression ratio, *r*, and the ratio of specific heats, γ.

a) Make a plot of the thermal efficiency, η_t, as a function of *r* for γ=1.4 (air) and γ=1.67 (monatomic gas such as helium). The range of *r* should extend from 1 to 14. (Note, these calculations and graph are very easy to do on spreadsheet such as **Excel**. If you don't know Excel, now is a good time to learn, and it's easy. The TAs are available to help).

b) Also calculate the specific work output, $w_{net} / c_p T_1$, as a function of *r* and the temperature ratio, $t=T_3/T_1$, for air with γ=1.4. Make a sketch of $w_{net} / c_p T_1$ as a function of *r* (with $1<r<14$) for *t*=2, 3 and 5. You may encounter some results that seem unphysical. If so, what's happening? Do not include the unphysical results in your sketch.

1.2 Closed Brayton cycle for power.

Consider a large stationary gas-turbine power plant that operates on an ideal, closed Brayton cycle and delivers a power output of 100 MW to an electric generator. The minimum temperature in the cycle is 300 K, and the maximum temperature is 1600 K. The minimum pressure in the cycle is 100 kPa, and the compressor pressure ratio is 14. The fluid is air, and the specific heats are constant.

a) For an ideal cycle, sketch the cycle on a T-s diagram, and calculate the power output of the turbine. What fraction of the turbine output power is required to drive the compressor? What is the thermal efficiency of this ideal cycle? What is the mass flow rate to produce the required power output?

b) Consider the same cycle, but now assume *isentropic* efficiencies of the compressor and turbine to be 85% and 88% respectively. In addition, there is a 2% pressure drop in both the high-temperature and the low-temperature heat exchangers. Hence, $P_3 = 0.98\ P_2$, and that $P_1 = 0.98\ P_4$. Repeat the calculations that were done in part (a).

c) Compare the thermal efficiencies found in parts (a) and (b) with that of a Carnot cycle operating between the same maximum and minimum temperatures.

d) Now consider the same cycle, but we're going to use *polytropic* efficiencies rather than isentropic efficiencies. For this part, do not include the pressure drops in the high and low-temperature heat exchangers. Assume that the *polytropic* compressor and turbine are 85 and 88%. For these conditions, repeat the calculations that were done in part (a).

1.3 Regenerator

Problem 11.82 in S,B & V.

Consider an ideal gas-turbine cycle with a pressure ratio across the compressor of 12 to 1. The compressor inlet is at 300 K and 100 kPa, and the cycle has a maximum temperature of 1600 K. An ideal regenerator (η_{reg}=1.0) is also incorporated in the cycle.

a) Find the thermal efficiency of the cycle with the regenerator using c_p = 1.0 kJ/kg K and γ= 1.4.

b) If the compression ratio is raised, T_4-T_2 decreases. At what compression ratio does T_2=T_4 making the regenerator ineffective?