UNIFIED ENGINEERING Fall 2003

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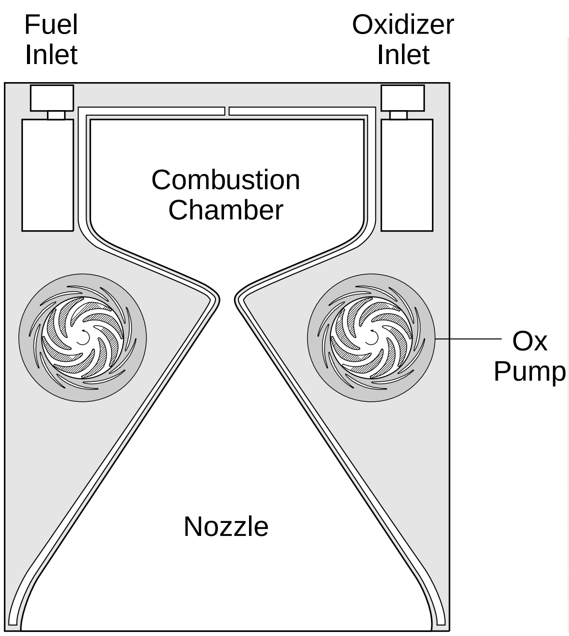
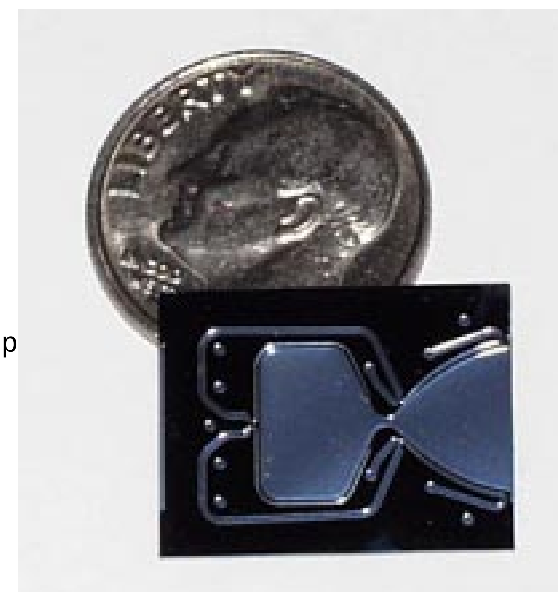
Problem T9 (Unified Thermodynamics)

There is a group of people at MIT who are working to develop micro-heat engines (gas turbines, rockets, etc.). These small (<1cm^3) engines are being manufactured using microfabrication technology similar to that developed to make microelectronic devices. Microengines have a very high ratio of surface area-to-volume (area scales with the characteristic length squared, volume scales with the characteristic length cubed). Therefore, it is no longer a good approximation to neglect heat transfer for many of the flow processes as we often do for larger devices.

Consider the following micro-rocket engine (it is about the thickness of a credit card and produces about 15N of thrust). It burns methane and oxygen and operates on an expander cycle like that described in homework T8. The combustion chamber pressure is 125atm and the combustion chamber temperature is 3000K. The velocities in the combustion chamber are small. Assume the flow behaves as an ideal gas with c_p = 1.5 kJ/kg-K, γ=1.2.





a) If the flow is adiabatic, what is the exit velocity when the rocket exhausts into standard atmospheric conditions? What are the static temperature and Mach number for this exit velocity?
b) What would the exit velocity, static temperature and Mach number be if the flow were fully-expanded to $p_e = 0$ in space?
c) Assume that about 20% of the total enthalpy of the flow in the combustion chamber is lost due to heat transfer to the walls of the combustion chamber. Now what is the exit velocity at standard atmospheric conditions and in space? (Assume that the chamber pressure is the same whether or not there is heat transfer.)

(LO# 4)