16.50 Spring 2001
Problem Set 6
Assigned: 3/15/01
Due: 3/21/01

A liquid bi-propellant micro-rocket uses as propellants, liquid oxygen and kerosene or RP-1. Following usual practice, we wish to cool the nozzle with the kerosene.

To keep the problem concise, we will focus on the throat of the nozzle, where the heat flux is the largest. **What we want is to keep the temperature T_s of the throat wall at its inner surface, where it is in contact with the hot gases, at or below 900 K.**

We will model the channel throat section and the cooling arrangement byflat plates. The combustion gases are in contact with one plate and flow left to right, with mass flux $(\rho u)^* = \dot{m}/A_t$ where At is the throat area and $\dot{m}$ is the flow rate. The coolant flows from right to left on the other side of the plate with mass flow $\dot{m}$/3, i.e. the oxidizer/fuel mass flow ratio is 2. Such an arrangement is termed "counterflow" and is often used in heat exchange systems. **You are at liberty to choose the height of the coolant flow passage, to meet the temperature constraint on the wall.**

Let's take the following values for the design parameters.

Throat width, D_t= 0.05 mm, Throat height = 0.25 mm
p_c= 100 atm
c*=1600 m/s
T_c= 3500 K
Combustion gas c_p= 1500 J/(kgK)
Combustion gas viscosity = 5x10^-5 kg/(ms)

Wall thickness t= 0.01 mm
Wall material is silicon, k= 1 watt/(cm.K) = 100 watt/(mK)

Coolant temperature = 100 K
Coolant c_p=1000 J/(kgK)
Coolant pressure = 200 atm
Coolant viscosity = 0.5x10^-5 kg/(ms)

Assume that the flow is fully developed turbulent flow in both the nozzle throat and the cooling passage.