16.50 Propulsion Systems
Year Unspecified

Quiz 1

One hour, open book, open notes

TRUE-FALSE QUESTIONS (50%)
Please include a 1-2 line explanation for each of your answers.

Statement	True	False
1. If one takes a given rocket, with a fixed chamber pressure, and replaces its operating gas by one with half the molecular mass, the thrust does not change.		
2. For any external pressure, adding segments to a supersonic nozzle (increasing A_e/A_t) always increases thrust.		
3. A conventional rocket nozzle operates on the ground with $P_e = 0.5\ atm$. A device is proposed that will force flow separation at the point in the nozzle where $P = 1\ atm$. This will increase thrust.		
4. A small test rocket is fired in vacuum and measurements are made of the jet flow speed many exhaust diameters downstream. When this is done using different expansion area ratios A_e/A_t, the downstream speed is found to be invariant.		
5. The method of characteristics can be used to design the contour of a nozzle, but only downstream from the throat.		
6. In a solid propellant rocket, increasing the throat area increases the thrust.		
7. The characteristic damping time of pressure oscillations inside a solid propellant rocket is proportional to the linear dimensions (assuming geometrically similar rockets).		
8. In an equilibrium nozzle expansion, dissociated species recombine fairly completely. This means the performance is the same as one would calculate if dissociation were ignored in the chamber.		
9. The chemical reactions that are selected for imposing equilibrium in the calculation of chamber temperature must be the ones that actually happen during combustion.		

10. Heat flux to the nozzle walls peaks at the throat because that is where stagnation temperature is maximum.		

PROBLEM (50%)

The gas leaving the combustion chamber of a LOX-LH rocket has the following characteristics:

- Molecular mass: $M = 13\ g/mol$
- Specific heat ratio: $\gamma = 1.26$
- Temperature: $T_c = 3600\ K$
- Pressure: $P_c = 210\ atm$
- Viscosity: $\mu_g = 3 \times 10^{-5} \left(\frac{T}{3000}\right)^{0.6} Kg/m/s$
- Prandtl's number: $P_r = 0.9$

The nozzle throat has a diameter $D_t = 0.277\ m$, and its first wall is a thin Copper shell which is cooled on its back side to $T_{wc} = 300\ K$. The thermal conductivity of Copper is $k = 360\ W/m/K$.

What is the maximum Copper thickness such that the hot-side temperature T_{wh} does not exceed $800\ K$?