16.50 Propulsion Systems
Spring 2012

Quiz 1 March 18, 2011

One hour, open book, open notes

TRUE-FALSE QUESTIONS:

Give an explanation for your answer in no more than 2 lines. For each question,

Right answer, valid explanation	4-5 points
Right answer, bad explanation	1-3 points
Right answer, no explanation	0 points
Wrong answer, some coherent argument	1-2 points
Wrong answer, no explanation (or bad explanation)	0 points

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Q1	The larger the weight/thrust ratio of a rocket engine, the higher the optimum initial acceleration of the vehicle.		
Q2	For a satellite in an elliptical orbit about Earth, the minimum ΔV required to escape occurs at perigee.		
Q3	The maximum payload that can be carried over a given ΔV with an Electric Propulsion thrust system of a fixed specific mass α increases with the thrusting time chosen.		
Q4	Since the flow speed at a choked throat is always sonic, and density is inversely proportional to temperature, the choked mass flow rate scales as $1/T_c$.		
Q5	A rocket nozzle is pressure-matched on the ground. As the rocket climbs and matching is lost, thrust decreases.		
Q6	If separation were somehow suppressed in an over-expanded nozzle with $P_e/P_0 < 0.4$, the thrust would increase.		
Q7	Reducing the throat area of a solid propellant rocket increases its thrust.		

Q8	In an externally heated rocket (like a nuclear or solar thermal rocket), dissociation of the gas increases thrust (for fixed chamber temperature and pressure).		
Q9	In a chemical (combustion) rocket, dissociation of the gas increases thrust (for fixed chamber pressure).		
Q10	Frozen flow expansion implies $\gamma = constant$.		
Q11	Of the two mechanisms affecting ablative cooling, heat absorption by vaporization of the surface material is dominant.		
Q12	Jet engines operate fuel-lean in order to maximize specific impulse.		

PROBLEM (40% of grade)

In a LOX-Kerosene rocket the gas-side "film coefficient", $h_g \equiv q_w/(T_c - T_{wh})$ is estimated to be $1.4 \times \frac{10^4 W}{m^2}/K$ when the chamber pressure is $P_c = 100\ atm.$, the chamber temperature is $T_c = 3300\ K$, and the hot-side wall temperature is $T_{wh} = 800K$. The first wall, separating the gas from the coolant, is a $2\ mm$ plate of Copper/Tungsten (thermal conductivity $k = 300W/m/K$. The coolant is the kerosene fuel, and it is estimated to be at $T_l = 430K$ when it arrives at the throat section after cooling the nozzle skirt.

a) Calculate the heat flux q_w at the throat.

b) By equating the same heat flux to that crossing the first wall, calculate the cool-side wall temperature T_{wc}.

c) By also equating q_w to the heat flux through the liquid-side boundary layer, calculate the required liquid-side film coefficient, h_l.

d) Assuming for the liquid $\rho_l = 800 kg/m^3$ and a specific heat $c_l = 1900\ J/kg/K$, and taking the liquid-side Stanton number to be 0.0015, calculate the implied liquid velocity u_l in the cooling passages.

e) **(For 10 points of extra credit)** If, due to excessive pressure drops, the maximum liquid velocity is $80\ m/s$, what would be the maximum chamber pressure P_c compatible with these conditions?