ASE 376K Homework # 2

2-1 A jet engine is designed for maximum thrust on a test stand (static thrust) of 53kN. The tests are conducted at 25C and 1 atm ambient conditions. The engine has a inlet mass flow rate of 77 kg/s at designed static thrust. Assume that the nozzle is perfectly expanded to begin with and check if that assumption may have a problem. The fuel used in the engine is Kerosene, which produces 46 MJ/kg of fuel combusted. Assume the engine design is such that the maximum allowable turbine temperature of 1500K is reached.

a) Assuming stoichiometric fuel-air ratio, compute the nozzle exit velocity.
b) The gases enter the turbine at relatively low velocity, and assume this is zero for this calculation. Assuming isentropic expansion across the turbine and nozzle, what is the exit temperature of the exhaust gases. The exhaust gases contain the mass fractions of CO_2, H_2O and N_2 in the stoichiometric ratio (See class notes). Assume that the R for the exhaust gases is close to that of air and gamma is a constant.
c) What is the Mach No of the exhaust gases? What does this tell you about the assumption of pe=pa?
d) What is the temperature rise of the air due to the stoichiometric combustion of Kerosene? Is the stoichiometric burning of Kerosene viable? Why or why not?
e) Usually in real operation, engines are operated in a lean fuel-air mixture. Assuming a lean fuel-air mixture, with a fuel-air ratio of 0.02, what is the compressor pressure ratio and efficiency of the Brayton cycle for the engine?

2-2 To estimate the effect of combustion on the gas constant of the combustion products in a jet engine, consider the following typical gas compositions:

		Mole Fraction		
	Molar Mass (kg/kmol)	Pure Air	Mixture 1 ($f = 3.32\times10^{-2}$)	Mixture 2 ($f = 1.66\times10^{-2}$)
N_2	28.0	0.783	0.761	0.775
O_2	32.0	0.208	0.101	0.155
Ar	40.0	9.30×10^{-3}	7.23×10^{-4}	7.37×10^{-4}
CO_2	44.0		6.47×10^{-2}	3.30×10^{-2}
H_2O	18.0		7.28×10^{-2}	3.71×10^{-2}

Calculate the gas constant of pure air, and of mixtures 1 and 2 assuming an ideal gas mixture in each case. For each case, what is the percentage error in R if one assumes R = 287 J/kg-K?

2-3. A rocket engine uses a H_2-O_2 mixture as a propellant. The mean molar mass of the propellant is 11.58 kg/kmol with ratio of specific heats $\gamma = 1.20$. The *stagnation* pressure at the throat of the nozzle is 8.26 MPa and the *static* temperature at the throat is 3300 K. The throat area A_t = 750.4 cm^2. The ratio of the exit plane area to the throat area is 39.8 and the static pressure at the exit plane of the nozzle is 18.1 kPa.

(a) Calculate the mass flow rate of propellant through the nozzle.
(b) Calculate the vacuum thrust of the rocket motor.

(Picture from http://www.boeing.com/defense-space/space/propul/SSME.html)