Homework # 1

1. Recall from thermodynamics that $c_p \equiv \left(\frac{\partial h}{\partial T}\right)_p$, $c_v \equiv \left(\frac{\partial e}{\partial T}\right)_v$ and $c_p - c_v = R$ so $c_p > c_v$. Use Gibbs' equation $(Tds = dh - vdp = de + pdv)$ to derive expressions for the slope of constant pressure and constant volume lines on a *T-s* diagram and prove that the slope of the constant volume line through a point is greater than the slope of a constant pressure line through the same point.

2. An aircraft engine draws in 370kg/s of air. The fuel ejectors in its combustion chambers pump 30kg/s of Kerosene. Kerosene combusts according to the equation,

$$C_{12}H_{26} + 18.5\ O_2 + 74\ N_2 = 12\ CO_2 + 13\ H_2O + 74\ N_2$$

a) Is the fuel-air ratio stoichiometric? Is it rich or lean?
b) Calculate the mole fractions of the combustion products for complete, stoichiometric combustion.
c) Assuming the combustion chamber has a uniform pressure of 50MPa, what are the partial pressures of the combustion gases?

3. For problem 2, assuming a fuel input for stoichiometric combustion, and assuming that the pressure at the exit of the engine is equalized to the ambient pressure, compute the thrust of the engine. The engine sees an incoming speed of M=0.8. Speed of sound is 340m/s. Kerosene produces has a heat of combustion (energy output) of 45MJ/kg. Assume 100% energy conversion from chemical energy to kinetic energy of air.

4. A blunt-nosed vehicle is flying in air at Mach 5, at an altitude where density is 0.1 kg/cu.m, temperature is 180K. Assuming a detached normal shock, compute the stagnation pressure at the nose of the vehicle.