EAS 4300 Homework 7:
Turbojet Engine

Due Thursday, April 7th at the beginning of class
NOTE: include a copy of your equations and with your plots

1. (50 points) A non-afterburning turbojet is being designed for operation at an altitude of 15 km and a Mach number of 1.8. The maximum stagnation temperature at the inlet of the turbine is 1500 K. The fuel is a jet fuel having a LHV of 43124 kJ/kg and f_{st} is 0.06. The following efficiencies apply at this Mach number:

$\eta_d = 0.9$	$\eta_b = 0.98$	$\eta_t = 0.92$
$\eta_c = 0.9$	$r_b = 0.97$	$\eta_n = 0.98$

   Use a gamma value of 1.4 up to the burner, and a value of 1.3 for the rest of the engine. Assume R is 0.287 kJ/kgK throughout the engine. Plot the specific thrust, TSFC, η_{th}, η_p, and η_o as a function of r_c, the total pressure ratio across the compressor. Is there an optimum r_c that minimizes TSFC? Is there an optimum r_c that maximizes specific thrust? Consider a range of r_c from 2 to 60. Assume the exhaust is ideally expanded. Also plot the nozzle area ratio as a function of r_c.

2. (50 points) Add an afterburner to the above situation. The maximum stagnation temperature downstream of the afterburner is 2000 K. The afterburner combustion efficiency η_{ab} is 0.95 and the total pressure ratio r_{ab} is 0.97. All other efficiencies remain the same. Use a gamma value of 1.4 up to the primary burner, and a value of 1.3 for the rest of the engine. Assume R is 0.287 kJ/kgK throughout the engine. Plot the specific thrust, TSFC, η_{th}, η_p, and η_o as a function of r_c, the total pressure ratio across the compressor. Consider a range of r_c from 2 to 60. Assume the exhaust is ideally expanded. Also plot the nozzle area ratio as a function of $r_{c.}$ Comment on the changes that occur due to the addition of the afterburner (i.e. compare the plots to that of problem 1). Note that the overall fuel-to-air ratio can not exceed the stoichiometric value ($f_b+f_{ab} \leq f_{st}$).

   Extra credit problem (10 points): the effect of assuming constant specific heats.
   Our stagnation relations for pressure and temperature assume constant specific heats. To attain a more accurate solution, we need to use the temperature dependent specific heats and specific heat ratios tabulated in appendix II from the book. Consider air at static conditions of 300 K and 1 atm. Construct a model to compute T_o/T and P_o/P as a function of Mach number from zero to four accounting for variable specific heats (i.e. use the values in the tables for air, and construct it as lookup function in your model), and compare to the results achieved using constant specific heats (i.e. our regular stagnation relations). A reminder, the stagnation process is modeled as isentropic, adiabatic, and no work. Plots the difference as a function of Mach number in terms of the absolute value of the relative error:

$$abs\left(\frac{\left(\frac{P_o}{P}\right)_{\text{variable specific heats}} - \left(\frac{P_o}{P}\right)_{\text{constant specific heats}}}{\left(\frac{P_o}{P}\right)_{\text{constant specific heats}}}\right) \qquad abs\left(\frac{\left(\frac{T_o}{T}\right)_{\text{variable specific heats}} - \left(\frac{T_o}{T}\right)_{\text{constant specific heats}}}{\left(\frac{T_o}{T}\right)_{\text{constant specific heats}}}\right)$$