MAE 150R
Rocket Propulsion Systems
Assignment 1: Due Monday, April 17, 2000
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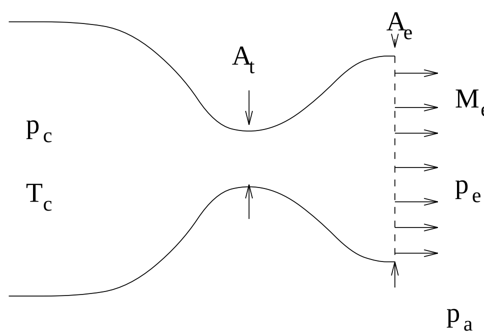
1. Problem 2-7 in Hill and Peterson's text.

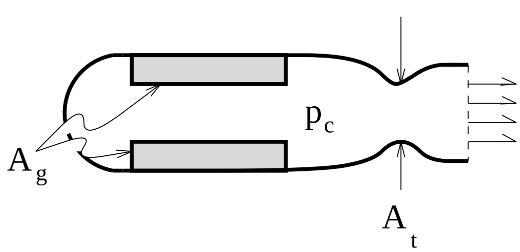
2. A rocket engine with an ideal nozzle is to operate at sea level using propellants whose combustion products have a ratio of specific heats $\gamma = 1.30$. Determine the required chamber pressure p_c and nozzle area ratio between the exit and the throat, A_e/A_t, if the nozzle exit Mach number is 2.40 and if the nozzle is perfectly expanded ($p_e = p_a$). A schematic for the problem is shown below.



3. The mass flow rate through a nozzle is given by

$$\dot{m} = 0.65(\frac{p_c A_t}{(RT_c)^{1/2}})$$

where p_c and T_c are the pressure and temperature in the rocket chamber and R is the gas constant of the gases in the chamber. The solid propellant burning rate (surface regression rate) can be expressed as $\dot{r} = a{p_c}^n$, where a and n are two empirical constants.



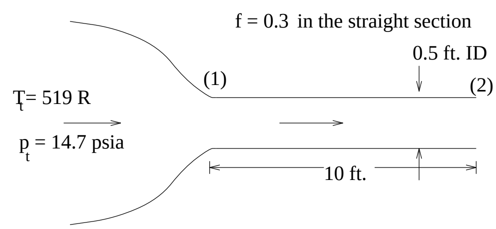
Show that the chamber pressure can be expressed as

$$p_c = (\frac{a\rho_p}{0.65})^{1/(1-n)}(\frac{A_g}{A_t})^{1/(1-n)}(RT_c)^{1/(2(1-n))}$$

where ρ_p is the propellant density and A_g is the grain surface burning area. HINT: use the continuity equation.

Note that the mass flow rate of gases into the combustion chamber is related to solid propellant properties and grain area. If the operating chamber pressure of a rocket motor is 3.5 MPa and n = 0.3, how much will the chamber pressure increase if a crack develops in the grain, increasing the burning area by 20%?

4. Standard atmospheric air ($T_t = 59$ °F, $p_t = 14.7$ psia) is drawn steadily through a frictionless and adiabatic converging nozzle into an adiabatic, constant cross section area duct. The duct is 10 ft long and has an inside diameter of 0.5 ft. The average **friction factor** for the duct may be estimated as being equal to 0.3.



   a.) What is the maximum mass flow rate in slugs/s through the duct?

   b.) For this maximum flowrate determine the values of static temperature, static pressure, stagnation temperature, stagnation pressure, and velocity at the inlet [section (1)] and exit [section (2)] of the constant area duct.

5. Your task is to design an "ideal" nozzle for a rocket that has to operate at 25 km altitude and produce a 5000 N thrust, where the combustion chamber pressure is 2.068 MPa and the chamber temperature is 2800 K. Assuming that $\gamma = 1.3$, that the gas constant for the combustion gases is R = 355.4 J/kg°K, and that the nozzle is perfectly expanded, determine the nozzle's throat area A_*, exit area A_e, throat velocity u_*, exit velocity u_e, and exit temperature T_e.