ASSIGNMENT # 7  
Due in class 11/26/13

**Note:** All reading and problems below are from Moran and Shapiro, Fundamentals of Engineering Thermodynamics.

**Suggested reading:** Chapter 9: *Compressible flow and Nozzles & Diffusers*

**PROBLEMS**

[1] (25%) Steam expands isentropically through a converging nozzle from a large tank at 10MPa, 360°C. The exit area of the nozzle is 5 cm². If the nozzle is choked at an exit pressure of 5.5 MPa, determine the exit velocity in m/s, the exit plane pressure in bar, and the mass flow rate of steam in kg/s, for back pressures of

(a) 8 MPa,  (b) 6 MPa,  (c) 4 MPa

**Hint:** notice that this is a converging nozzle. The pressure at the exit plane is the pressure right at the last cross section. The back pressure is the outlet pressure (after the last cross section). When the back pressure is equal to the critical pressure at which Mach=1 at the exit, then the nozzle is choked. If you keep lowering the back pressure nothing will change inside the nozzle, even at its last cross section (the exit plane) where Mach will remain equal to 1. There are no shocks here because the flow never becomes supersonic inside the nozzle.

[2] (25%) A converging-diverging nozzle operating at steady state has a throat area of 3 cm² and an exit area of 6 cm². Air as an ideal gas with k=1.4 enters the nozzle at 8 bar, 400K, and a Mach number of 0.2, and flows isentropically throughout (no shocks). If the nozzle is choked, and the diverging portion acts as a supersonic nozzle, determine the mass flow rate, in kg/s, the Mach number, the pressure, in bar, and the temperature, in K, at the exit. Repeat if the diverging portion acts as a subsonic diffuser. Use cold-air analysis with constant specific heats.

[3] (25%) Air at \(p_0=1.4\) bar, \(T_0=280\) K expands isentropically through a converging nozzle and discharges to the atmosphere at 1 bar. The exit plane area is \(0.0013\)m². Use the constant specific heat approximation.

(a) Determine the mass flow rate, in kg/s
(b) If the pressure \(p_0\) were increased to 2 bar, what would be the mass flow rate, in kg/s ?
Air enters a nozzle operating at steady state, with negligible velocity at 100 lbf/in², 860 °R, and expands isentropically. For a mass flow rate of 4 lb/s, calculate the velocity in ft/s, the Mach number, and the cross sectional area, in ft², at locations within the nozzle where the pressure is 80 lbf/in².