1. Show that for isentropic flow of a perfect gas if a pitotstatic probe measures p_0, p, and T_0, the gas velocity can be calculated from:

$$V^2 = 2c_pT_0\left[1 - \left(\frac{p}{p_0}\right)^{(k-1)/k}\right]$$

What would be a source of error if a shock wave were formed in front of the probe?

2. Air flows steadily from a reservoir at 20°C through a nozzle of exit area 20 cm^2 and strikes a vertical plate as in Fig. P2. The flow is subsonic throughout. A force of 135 N is required to hold the plate stationary. Compute (a) V_e, (b) Ma_e, and (c) p_0 if p_a = 101 kPa.

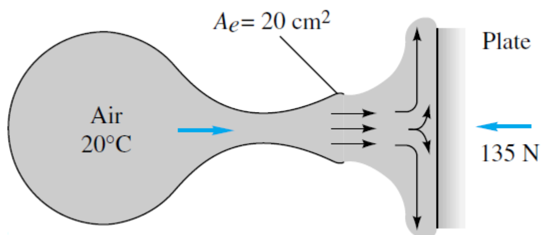

Fig.P2

3. Air flows from a tank through a nozzle into the standard atmosphere, as in Fig. P3. A normal shock stands in the exit of the nozzle, as shown. Estimate (a) the pressure in the tank and (b) the mass flow.

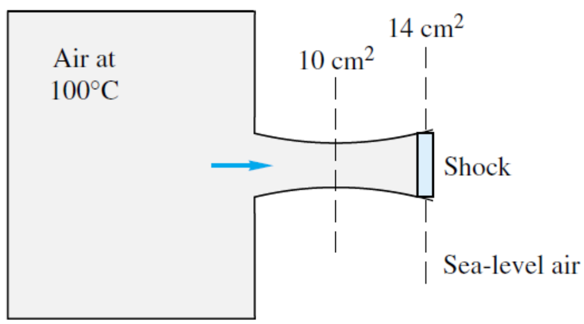

Fig.P3

4. The orientation of a hole can make a difference. Consider holes A and B in Fig. P4, which are identical but reversed. For the given air properties on either side, compute the mass flow through each hole and explain why they are different.

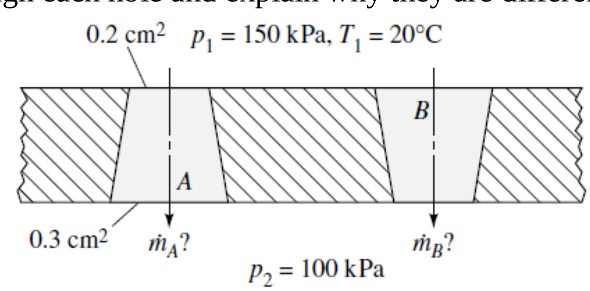

Fig.P4

5. Air flows through a duct as in Fig. P5, where A_1 = 24 cm2, A_2 = 18 cm2, and A_3 = 32 cm^2. A normal shock stands at section 2. Compute (a) the mass flow, (b) the Mach number, and (c) the stagnation pressure at section 3.

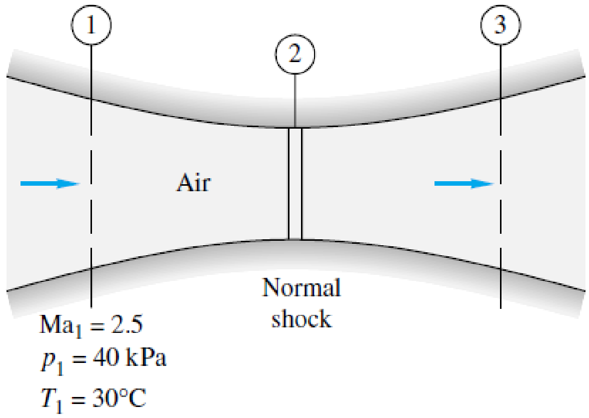

Fig.P5

6. Air flows steadily from a tank through the pipe in Fig. P6. There is a converging nozzle on the end. If the mass flow is 3 kg/s and the nozzle is choked, estimate (a) the Mach number at section 1 and (b) the pressure inside the tank.

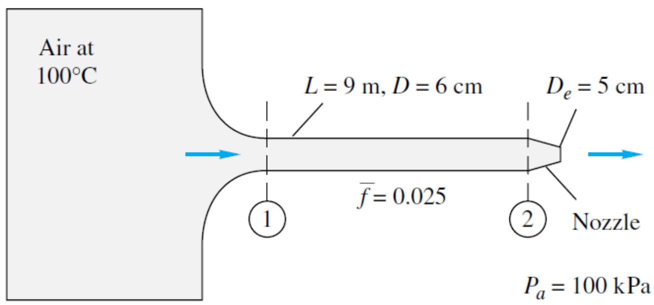

Fig.P6

7. Air at 550 kPa and 100°C enters a smooth 1-m-long pipe and then passes through a second smooth pipe to a 30 kPa reservoir, as in Fig. P7. Using the Moody chart to compute *f*, estimates the mass flow through this system. Is the flow choked?

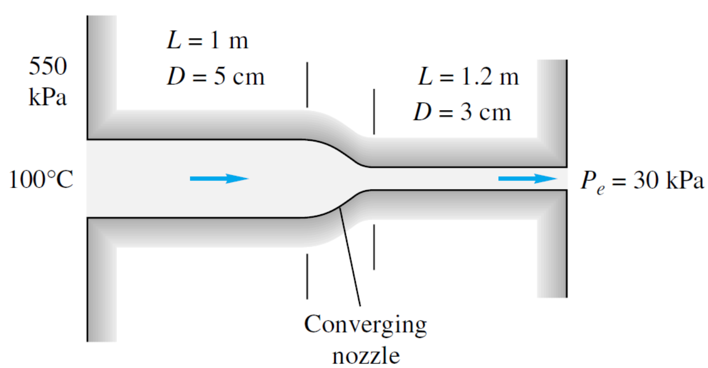

Fig.P7

8. A fuel-air mixture, assumed equivalent to air, enters a duct combustion chamber at $V_1 = 104$ m/s and $T_1 = 300$ K. What amount of heat addition in kJ/kg will cause the exit flow to be choked? What will be the exit Mach number and temperature if 504 kJ/kg is added during combustion?

9. A double-tank system in Fig. P9 has two identical converging nozzles of 1 in^2 throat area. Tank 1 is very large, and tank 2 is small enough to be in steady-flow equilibrium with the jet from tank 1. Nozzle flow is isentropic, but entropy changes between 1 and 3 due to jet dissipation in tank 2. Compute the mass flow.

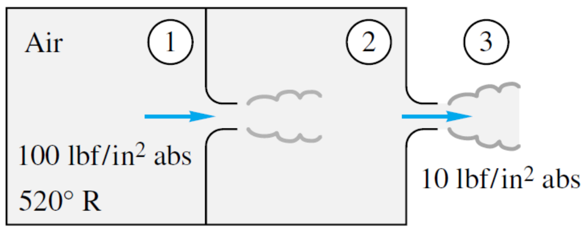

Fig. P9

10. Air in a tank at 120 kPa and 300 K exhausts to the atmosphere through a 5 cm2-throat converging nozzle at a rate of 0.12 kg/s. What is the atmospheric pressure? What is the maximum mass flow possible at low atmospheric pressure?
Show that the thrust of a rocket engine exhausting into a vacuum is given by:

$$F = \frac{p_0 A_e (1 + k\,\mathrm{Ma}_e^2)}{\left(1 + \frac{k-1}{2}\mathrm{Ma}_e^2\right)^{k/(k-1)}}$$

where A_e = exit area
Ma_e = exit Mach number
p_0 = stagnation pressure in combustion chamber
Note that stagnation temperature does not enter into the thrust.

11. Water flow in a rectangular channel is to be metered by a thin-plate weir with side contractions, as in Table 10.1b, with L = 6 ft and Y = 1 ft. It is desired to measure flow rates between 1500 and 3000 gal/min with only a 6-in change in upstream water depth. What is the most appropriate length for the weir width b?

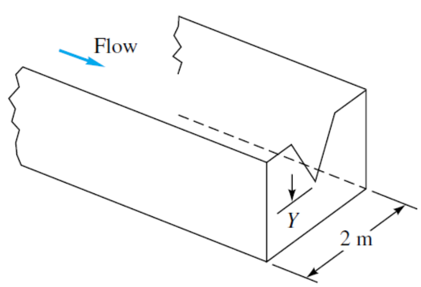

Fig. P11