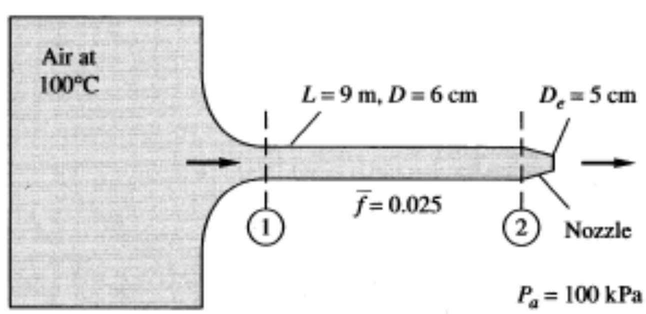
Gas Dynamics

Assignment #4: Adiabatic flow in pipes with friction and Oblique shocks

1. Fill the following table for change in flow properties inside an adiabatic duct with friction:

Property	Subsonic flow (M<1)	Supersonic flow (M>1)
Static pressure (p)	Decrease	Increase
Static temperature		
Density		
Velocity		
Mach number		
Stagnation pressure		
Stagnation temperature		
4fl/D		
Entropy (s)		

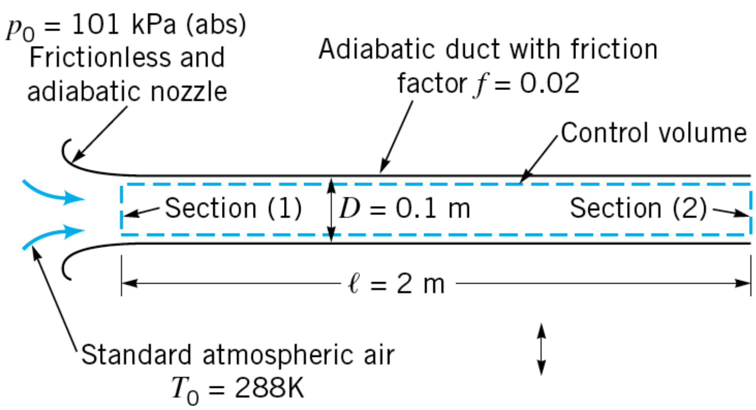
2. Air enters a 3-cm diameter pipe 15 m long at V1 = 73 m/s, p1 = 550 kPa, and T1 = 60°C. The friction factor is *4f* = 0.018. Compute V2, p2, T2, and p02 at the end of the pipe. How much additional pipe length would cause the exit flow to be sonic?
3. Air enters an adiabatic duct of L/D = 40 at V1 = 170 m/s and T1 = 300 K. The flow at the exit is choked. What is the average friction factor in the duct?
4. Air, supplied at p0 = 700 kPa and T0 = 330 K, flows through a converging nozzle into a pipe of 2.5-cm diameter which exits to a near vacuum. If *4f* = 0.022 , what will be the mass flow through the pipe if its length is (a) 0 m, (b) 1 m, and (c) 10 m?
5. Air flows steadily from a tank through the pipe in the Fig. There is a converging nozzle on the end. If the mass flow is 3 kg/s and the flow is choked, estimate (a) the Mach number at section 1; and (b) the pressure in the tank.



6. In the previous problem, let the tank pressure be 700 kPa, and let the nozzle be *choked*. Determine (a) Ma_2; and (b) the mass flow. Keep $T_o = 100°C$.

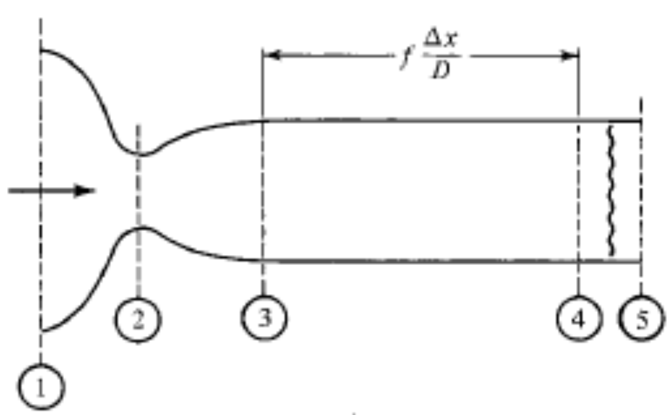
7. Air enters a 5-cm-diameter pipe at p1 = 200 kPa and T1 = 350 kPa. The downstream receiver pressure is 74 kPa and the friction factor is 4f = 0.02. If the exit is choked, what is (a) the length of the pipe, and (b) the mass flow? (c) If p1, T1 and preceiver stay the same, what pipe length will cause the mass flow to increase by 50% over (b)? Hint: In (c) the exit pressure does not equal receiver pressure.

8. Air, supplied by Standard atmospheric air (T_0 = 288 K, P_0 = 101 kPa) is drawn steadily through a frictionless, adiabatic converging nozzle into an adiabatic, constant-area duct as shown in the Fig. The duct is 2-m long and has an inside diameter of 0.1 m. The average friction factor for the duct is estimated as being equal to ($4f$ = 0.02). What is the maximum mass flow rate through the duct? For this maximum flow rate, determine the values of static temperature, static pressure, stagnation temperature, stagnation pressure, and velocity at the inlet and exit of the duct.



9. A large chamber contains air at a temperature of 300 K and a pressure of 8 bar. The air enters a converging–diverging nozzle with an area ratio of 2.4. A constant-area duct is attached to the nozzle and a normal shock stands at the exit plane. Back pressure is 3 bar abs. Assume the entire system to be adiabatic and neglect friction in the nozzle. Compute the $4fL/D$ for the duct.

<u>**Important hint:**</u> Normal shocks doe not change P^* (i.e. P^* is the same before and after the shock).



10. Conditions before an oblique shock are $T_1 = 40°C$, $p_1 = 1.2$ bar, and $M_1 = 3.0$. The shock is observed at $\theta = 45°$ to the approaching air flow.**(a)** Determine the Mach number and flow direction (δ) after the shock. **(b)** What are the temperature and pressure after the shock?

11. An oblique shock forms in air at an angle of $\theta = 30°$. Before passing through the shock, the air has a temperature of 288 K, a pressure of 69 kPa, and is traveling at $M = 2.6$. **(a)** Compute the normal and tangential velocity components before and after the shock. **(b)** Determine the temperature and pressure after the shock. **(c)** What is the deflection angle?