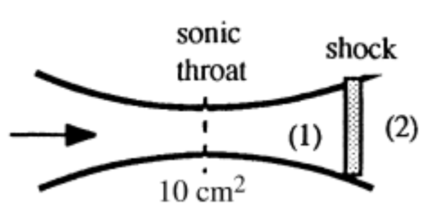
Gas Dynamics

Assignment #3: Normal shock waves

1. Fill the following table for change in flow properties after a normal shock

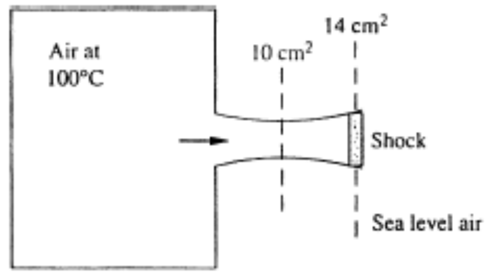
Property	Increase or decrease
Static pressure (p)	Increase
Static temperature	
Density	
Velocity	
Mach number	
Stagnation pressure	
Stagnation temperature	
A^*	
Entropy (s)	

2. Air, supplied by a reservoir at 450 kPa, flows through a converging-diverging nozzle whose throat area is 12 cm^2. A normal shock stands where A_1 = 20 cm^2. (a) Compute the pressure just downstream of this shock. Still farther downstream, where A_3 = 30 cm_2, estimate (b) p_3; (c) A_3*; and (d) M_3. (Ans. 261 kPa, 303 kPa, 16.5 cm^2, M_3=0.34)
3. Air from a reservoir at 20°C and 500 kPa flows through a duct and forms a normal shock downstream of a throat of area 10 cm^2. By an odd coincidence it is found that the stagnation pressure downstream of this shock exactly equals the throat pressure. What is the area where the shock wave stands? (Ans. 24.7 cm^2)



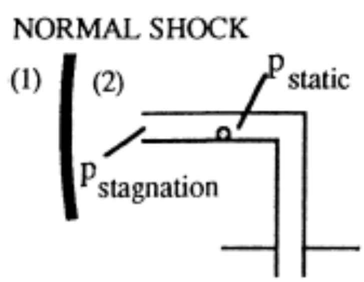
4. Repeat problem #2 except this time let the odd coincidence be that the static pressure downstream of the shock exactly equals the throat pressure. What is the area where the shock wave stands? (Ans. 19.2 cm^2)

5. Air flows from a tank through a nozzle into the standard atmosphere (p = 101.3 kPa), as shown in the figure. A normal shock stands in the exit of the nozzle, as shown. Estimate (a) the tank pressure; and (b) the mass flow. (Ans. 1591 kPa, 0.333 kg/s)

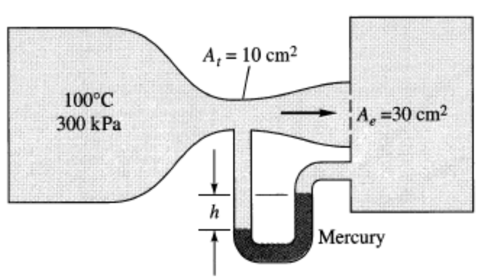


6. Air, at stagnation conditions of 450 K and 250 kPa, flows through a nozzle. At section 1, where the area = 15 cm^2, there is a normal shock wave. If the mass flow is 0.4 kg/s, estimate (a) the Mach number; and (b) the stagnation pressure just downstream of the shock. (Ans. M = 0.566, 172 kPa)

7. When a pitot tube such as in the figure is placed in a supersonic flow, a normal shock will stand in front of the probe. Suppose the probe reads $\mathbf{p}_0$ = 190 kPa and **p** = 150 kPa. If the stagnation temperature is 400 K, estimate the (supersonic) Mach number and velocity upstream of the shock. (Ans. M = 1.92, 585 m/s)



8. Air flows through a converging-diverging nozzle between two large reservoirs, as in the figure. A mercury manometer reads h = 15 cm. Estimate the downstream reservoir pressure. Is there a shock wave in the flow? If so, does it stand in the exit plane or farther upstream? (Ans. 138.5 kPa, A normal shock wave stands upstream of the exit plane)



9. In the previous problem, what would be the mercury manometer reading if the nozzle were operating exactly at supersonic "design" conditions? (Ans. h = 1.09 m)

10. Air flows through a duct as in the figure, where $\mathbf{A}_1 = 24\ cm^2$, $\mathbf{A}_2 = 18\ cm^2$, and $\mathbf{A}_3 = 32\ cm^2$. A normal shock stands at section 2. Compute (a) the mass flow, (b) the Mach number, and (c) the stagnation pressure at section 3.
(Ans. 0.96 kg/s, $M_3 = 0.27$, $P_{03} = 435$ kPa)