problems of Chapter 4-1
(Oblique shock and expansion waves)

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Relation between the units:

1 ft=0.3048m;1lb=0.454 kg; 1lb/ft^2=47.89N/m^2=47.89 Pa; 1^{o}R=5/9K

Due October 29^{th}, 2024

4.1 Consider an oblique shock wave with wave angle equal to 35^o. Upstream of the wave $p_1 = 2000 lb/ft^2$, $T_1 = 520^o R$, and $V_1 = 3355 ft/s$. Calculate p_2, T_2, V_2, and the flow deflection angle.

4.2 Consider a wedge with a half angle of 10^o flying at Mach 2. Calculate the ratio of total pressure across the shock wave emanating from the leading edge of the wedge.

4.3 Calculate the maximum surface pressure (in units of Newton per square meter) that can be achieved on the forward face of a wedge flying at Mach 3 at standard sea level conditions ($p_1 = 1.01 \times 10^5$ N/m^2) with an attached shock wave.

4.4 In the flow past a compression corner, the upstream Mach number and pressure are 3.5 and 1 atm, respectively. Downstream of the corner, the pressure is 5.48 atm. Calculate the deflection angle of the corner.

4.5 Consider a 20^o half angle wedge in a supersonic flow at Mach 3 at standard sea level ($p_1 = 2116 lb/ft^2 = 1 atm$ and $T_1 = 519^o R = 288K$). Calculate the wave angle, and the surface pressure, temperature, and Mach number.

4.10 Consider the flow past a 30^o expansion corner, as sketched in Fig. 4.32.The upstream conditions are $M_1 = 2, p_1 = 3$ atm, and $T_1 = 400$ K, calculate the following downstream conditions: M_2, p_2, T_2, T_{02}, and p_{02}.

4.11 For a given Prandtl-Meyer expansion, the upstream Mach number is 3 and the pressure ratio across the wave is $p_2/p_1 = 0.4$. Calculate the angle of the forward and the rearward Mach lines of the expansion fan relative to the free stream direction.

4.12 Consider a supersonic flow with upstream Mach number of 4 and pressure of 1 atm. This flow is first expanded around an expansion corner with $\theta = 15^o$, and then compressed through a compression corner with equal angle $\theta = 15^o$, so that it is returned to its original upstream direction. Calculate the Mach number and pressure downstream of the compression corner.

4.14 Consider a supersonic flow past a compression corner with $\theta = 20^o$. The upstream properties are $M_1 = 3$ and $p_1 = 2116 \mathrm{lb/ft}^2$. A Pitot tube is inserted in the flow downstream of the corner. Calculate the value of pressure measured by the Pitot tube.

4.20 The flow of a chemically reacting gas is sometimes approximated by the use of relations obtained assuming a calorically perfect gas, such as in this chapter, but using an "effective gamma," a ratio of specific heats less than 1.4.

Consider the Mach 3 flow of chemically reacting air, where the flow is approximated by a ratio of specific heats equal to 1.2. If this gas flows over a compression corner with a deflection angle of 20 degrees, calculate the wave angle of the oblique shock. Compare this result with that for ordinary air with a ratio of specific heats equal to 1.4. What conclusion can you make about the general effect of a chemically reacting gas on wave angle?

4.21For the two cases treated in Problem 4.20, calculate and compare the pressure ratio (shock strength) across the oblique shock wave. What can you conclude about the effect of a chemically reacting gas on shock strength?