Problems of Chapter 1

September 29, 2023

Relation between the units:

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

Read carefully chapter 1, especially Ch 1.3 and 1.4. You will found the questions are rather easy to solve :).
Deadline: September 22nd, 2023

1.1 At the nose of a missile in flight, the pressure and temperature are 5.6 atm and 850°R, respectively. Calculate the density and specific volume. (Note: 1 atm = 2116 lb/ft^2.)

1.2 In the reservoir of a supersonic wind tunnel, the pressure and temperature of air are 10 atm and 320 K, respectively. Calculate the density, the number density, and the mole-mass ratio. (Note: 1 atm = 1.01×10^5 N/m^2.)

1.3 For a calorically perfect gas, derive the relation $c_p - c_v = R$. Repeat the derivation for a thermally perfect gas.

1.4 The pressure and temperature ratios across a given portion of a shock wave in air are $p_2/p_1 = 4.5$ and $T_2/T_1 = 1.687$, where 1 and 2 denote conditions ahead of and behind the shock wave, respectively. Calculate the change in entropy in units of (a) (ft · lb)/(slug·^{o}R) and (b) J/(kg· K).

1.5 Assume that the flow of air through a given duct is isentropic. At one point in the duct, the pressure and temperature are $p_1 = 1800$ lb/ft^2 and $T_1 = 500$ ^{o}R, respectively. At a second point, the temperature is 400 ^{o}R. Calculate the pressure and density at this second point.

1.6 Consider a room that is 20 ft long, 15 ft wide, and 8 ft high. For standard sea level conditions, calculate the mass of air in the room in slugs. Calculate the weight in pounds. (Note: If you do not know what standard sea level conditions are, consult any aerodynamics text, such as Refs. 1 and 104, for these values. Also, they can be obtained from any standard atmosphere table.)

1.7 In the infinitesimal neighborhood surrounding a point in an inviscid flow, the small change in pressure, dp, that corresponds to a small change in velocity, dV, is given by the differential relation $dp = -\rho V dV$. (This equation is called Euler's Equation; it is derived in Chap. 6.) a. Using this relation, derive a differential relation for the fractional change in density, $d\rho/\rho$, as a function of the fractional change in velocity, dV/V, with the compressibility τ as a coefficient.
b. The velocity at a point in an isentropic flow of air is 10 m/s (a low speed flow), and the density and pressure are 1.23 kg/m^3 and 1.01×10^5 N/m^2, respectively (corresponding to standard sea level conditions). The fractional change in velocity at the point is 0.01. Calculate the fractional change in density.
c. Repeat part (b), except for a local velocity at the point of 1000 m/s (a high-speed flow). Compare this result with that from part (b), and comment on the differences.