Problems of Ch3 Part 1

September 25, 2023

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 8^{th}, 2023

3.1 At a given point in the high-speed flow over an airplane wing, the local Mach number, pressure and temperature are 0.7, 0.9 atm and 250 K, respectively. Calculate the values of p_0,T_0,p^*,T^*, and a^* at this point.

3.2 At a given point in a supersonic wind tunnel, the pressure and temperature are 5×10^4 N/m^2 and 200 K, respectively. The total pressure at this point is 1.5×10^6 N/m^2. Calculate the local Mach number and total temperature.

3.3 At a point in the flow over a high speed missile, the local velocity and temperature are 3000 ft/s and $500^o R$, respectively. Calculate the Mach number and the characteristic Mach number M^* at this point.

3.4 Consider a normal shock wave in air. The upstream conditions are given by M_1=3, $p_1 = 1$ atm, and ρ_1 =1.23kg/m^3. Calculate the downstream values of $p_2, T_2, \rho_2, M_2, u_2, p_{02}$, and T_{02}.

3.5 Consider a Pitot static tube mounted on the nose of an experimental airplane. A Pitot tube measures the total pressure at the tip of the probe (hence sometimes called the Pitot pressure), and a Pitot static tube combines this with a simultaneous measurement of the free stream static pressure. The Pitot and free-stream static measurements are given below for three different flight conditions. Calculate the free stream Mach number at which the airplane is flying for each of the three different conditions:
a. Pitot pressure=$1.22 \times 10^5 N/m^2$, static pressure=1.01×10^5 N/m^2;
b. Pitot pressure=7222lb/ft^2, static pressure=2116 lb/ft^2;
c. Pitot pressure=13107lb/ft^2, static pressure=1020 lb/ft^2.

3.6 Consider compression of air by means of (a) a shock compression and (b) isentropic compression. Starting from the same initial condition of p_1 and v_1, plot to scale the pv diagram for both compression processes on the same graph. From the comparison, what can you say about the effectiveness of shock versus isentropic compression?

3.7 During the entry of the Apollo vehicle into the Earth's atmosphere, the Mach number at a given point on the trajectory was Ma=38 and the atmosphere temperature was 270K. Calculate the temperature at the stagnation point of the vehicle, assuming a calorically perfect gas with $\gamma = 1.4$. Do you think this is an accurate calculation? If not, why? If not, is your answer an overestimate or underestimate?