PROBLEMS

(*Note*: Use the tables at the end of this book as extensively as you wish to solve the following problems. Also, when the words "pressure" and "temperature" are used without additional modification, they refer to the *static* pressure and temperature.)

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_o, T_o, 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°R, respectively. Calculate the Mach number M 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 $\rho_1 = 1.23$ kg/m^3. Calculate the downstream values of p_2, T_2, ρ_2, M_2, u_2, p_{o_2}, and T_{o_2}.

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 = 1.22×10^5 N/m^2, static pressure = 1.01×10^5 N/m^2
(*b*) Pitot pressure = 7222 lb/ft^2, static pressure = 2116 lb/ft^2
(*c*) Pitot pressure = 13107 lb/ft^2, static pressure = 1020 lb/ft^2

3.6 Consider the compression of air by means of (*a*) shock compression and (*b*) isentropic compression. Starting from the same initial conditions of p_1 and v_1, plot to scale the pv diagrams 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 space vehicle into the Earth's atmosphere, the Mach number at a given point on the trajectory was $M = 38$ and the atmosphere temperature was 270 K. 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?

3.8 Consider air entering a heated duct at $p_1 = 1$ atm and $T_1 = 288$ K. Ignore the effect of friction. Calculate the amount of heat per unit mass (in joules per kilogram) necessary to choke the flow at the exit of the duct, as well as the pressure and temperature at the duct exit, for an inlet Mach number of

(*a*) $M_1 = 2.0$ (*b*) $M_1 = 0.2$.

3.9 Air enters the combustor of a jet engine at $p_1 = 10$ atm, $T_1 = 1000$°R, and $M_1 = 0.2$. Fuel is injected and burned, with a fuel-air ratio (by mass) of 0.06. The heat released during the combustion is 4.5×10^8 ft/lb per slug of fuel. Assuming one-dimensional frictionless flow with $\gamma = 1.4$ for the fuel-air mixture, calculate M_2, p_2, and T_2 at the exit of the combustor.

3.10 For the inlet conditions of Prob. 3.9, calculate the maximum fuel-air ratio beyond which the flow will be choked at the exit.

3.11 At the inlet to the combustor of a supersonic combustion ramjet (SCRAMjet), the flow Mach number is supersonic. For a fuel-air ratio (by mass) of 0.03 and a combustor exit temperature of 4800°R, calculate the inlet Mach number above which the flow will be unchoked. Assume one-dimensional frictionless flow with $\gamma = 1.4$, with the heat release per slug of fuel equal to 4.5×10^8 ft · lb.

3.12 Air is flowing through a pipe of 0.02-m inside diameter and 40-m length. The conditions at the exit of the pipe are $M_2 = 0.5$, $p_2 = 1$ atm, and $T_2 = 270$ K. Assuming adiabatic, one-dimensional flow, with a local friction coefficient of 0.005, calculate M_1, p_1, and T_1 at the entrance to the pipe.

3.13 Consider the adiabatic flow of air through a pipe of 0.2-ft inside diameter and 3-ft length. The inlet flow conditions are $M_1 = 2.5$, $p_1 = 0.5$ atm, and $T_1 = 520$°R. Assuming the local friction coefficient equals a constant of 0.005, calculate the following flow conditions at the exit: M_2, p_2, T_2, and p_{o_2}.

3.14 The stagnation chamber of a wind tunnel is connected to a high-pressure air bottle farm which is outside the laboratory building. The two are connected by a long pipe of 4-in inside diameter. If the static pressure ratio between the bottle farm and the stagnation chamber is 10, and the bottle-farm static pressure is 100 atm, how long can the pipe be without choking? Assume adiabatic, subsonic, one-dimensional flow with a friction coefficient of 0.005.

3.15 Starting with Eq. (3.95), derive in detail Eq. (3.96).

مسایل ۸ تا ۱۵ در زمینه اثرات افزایش گرما و اصطکاک مفید است.