Problem 1.1

For most gases at standard or near standard conditions, the relationship among pressure, density, and temperature is given by the perfect gas equation of state: $p = \rho RT$, where R is the specific gas constant. For air at near standard conditions, $R = 287$ J/(kg · K) in the International System of Units and $R = 1716$ ft · lb/(slug · °R) in the English Engineering System of Units. (More details on the perfect gas equation of state are given in Chapter 7.) Using the above information, consider the following two cases:

a. At a given point on the wing of a Boeing 727, the pressure and temperature of the air are 1.9×10^4 N/m^2 and 203 K, respectively. Calculate the density at this point.

b. At a point in the test section of a supersonic wind tunnel, the pressure and density of the air are 1058 lb/ft^2 and 1.23×10^{-3} slug/ft^3, respectively. Calculate the temperature at this point.

Solution

Part (a)

Solve the ideal gas law for the density ρ and make sure the units cancel appropriately (1 J = 1 N · m).

$$\rho = \frac{p}{RT} = \frac{1.9 \times 10^4 \ \frac{\text{N}}{\text{m}^2}}{\left(287 \ \frac{\text{J}}{\text{kg}\cdot\text{K}}\right)(203 \text{ K})} \approx 0.33 \ \frac{\text{kg}}{\text{m}^3}$$

Part (b)

Solve the ideal gas law for the temperature T and make sure the units cancel appropriately.

$$T = \frac{p}{R\rho} = \frac{1058 \ \frac{\text{lb}}{\text{ft}^2}}{\left(1716 \ \frac{\text{ft}\cdot\text{lb}}{\text{slug}\cdot{}^\circ\text{R}}\right)\left(1.23 \times 10^{-3} \ \frac{\text{slug}}{\text{ft}^3}\right)} \approx 501 \ {}^\circ\text{R}$$