$$\boldsymbol{P_{18km} = 7537.31\ Pa} \leftarrow \textbf{Answer}$$

Now for the standard atmospheric value of density at 18km altitude,

$$\frac{\rho_{18km}}{\rho_{12km}} = e^{\left(\frac{-g_0}{RT}\right)(h_{18km} - h_{12km})}$$

$$\rho_{18km} = \left(3.1194 \text{ x } 10^{-1}\,\frac{kg}{m^3}\right) \cdot e^{\frac{-9.8\,\frac{m}{s^2}}{\left(287.08\,\frac{J}{kg \cdot K}\right)(216.66\,K)}(6000\,m)}$$

$$\boldsymbol{\rho_{18km} = 0.121\ \frac{kg}{m^3}} \leftarrow \textbf{Answer}$$

Isothermal region is within the range beginning from h = 11 km above sea level condition to h = 25 km which means temperature is constant. And so,

$$T_{12km} = \boldsymbol{T_{18km} = 216.66\ K} \leftarrow \textbf{Answer}$$

3.2 Consider an airplane flying at some real altitude. The outside pressure and temperature are 2.65 x 10^4 N/m^2 and 200 K, respectively. What are the pressure and density altitudes?

Given:

$$P_1 = 2.65 \text{ x } 10^4\ \frac{N}{m^2}\ ;\ T_1 = 200\text{ K}\ ;\ h_P = ?\ ;\ h_\rho = ?$$

Solution:

To solve the pressure altitude by using the given pressure, we need to use and consider the pressure variation at gradient region of 0-11 km.

$$\frac{P_1}{P_0} = \left[\frac{T_1}{T_0}\right]^{5.26}$$

Because $T_1 = T_0 + \lambda h_P$, so

$$\frac{P_1}{P_0} = \left[\frac{T_0 + \lambda h_P}{T_0}\right]^{5.26}$$

Chapter 4 Basic Aerodynamics

4.1 Consider the incompressible flow of water through a divergent duct. The inlet velocity and area are 5 ft/s and 10 ft^2, respectively. If the exit area is four times the inlet area, calculate the water flow velocity at the exit.

Given:

$$v_1 = 5\,\frac{ft}{s}\ ;\ A_1 = 10\,ft^2\ ;\ A_2 = 4A_1\ ;\ v_2 = ?$$

Solution:

So considering the flow is incompressible which means the density, ρ, is assumed to be constant and has no change, therefore the volume flow rate of inlet to exit are equal.

$$Q_1 = Q_2$$

If,

$$Q = Av$$

Then,

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{A_1 v_1}{4A_1} = \frac{5\,\frac{ft}{s}}{4}$$

$$\boldsymbol{v_2 = 1.25\,\frac{ft}{s}}$$ **←Answer**

4.2 In the above problem, calculate the pressure difference between the exit and the inlet. The density of water is 62.4 lb$_m$/ft^3.

Given:

$$\rho = 62.4\,\frac{lb_m}{ft^3}\ ;\ P_2 - P_1 = \Delta P = ?$$

exit, the pressure is 1 atm. Calculate the temperature and density of the flow at the exit. Assume the flow is isentropic and, of course, compressible.

Given:

$$P_R = 10 \text{ atm} \;\; ; \;\; T_R = 300\,K \;\; ; \;\; P_E = 1\,atm \;\; ; \;\; T_E = ? \;\; ; \;\; \rho_E = ?$$

Solution:

Let us use the formula for isentropic condition.

$$\left[\frac{T_1}{T_3}\right] = \left[\frac{P_1}{P_3}\right]^{\frac{k-1}{k}}$$

$$T_3 = \frac{T_1}{\left[\frac{P_1}{P_3}\right]^{\frac{k-1}{k}}} = \frac{300\,K}{\left[\frac{10\,atm}{1\,atm}\right]^{\frac{1.4-1}{1.4}}}$$

$$\boldsymbol{T_3 = 155.38\,K} \leftarrow \textbf{Answer}$$

Because we already have the value of pressure and temperature at the exit section, we can use the equation of state to get the density.

$$P_3 = \rho_3 R T_3$$

$$P_3 = \frac{P_3}{RT_3} = \frac{1\,atm \times \frac{101325\,Pa}{1\,atm}}{\left(287.08\,\frac{J}{kg \cdot K}\right)(155.38\,K)}$$

$$\boldsymbol{\rho_3 = 2.27\,\frac{kg}{m^3}} \leftarrow \textbf{Answer}$$

Chapter 5 Airfoils, Wings, and Other Aerodynamic Shapes

5.3 Consider a rectangular wing mounted in a low-speed subsonic wing tunnel. The wing model completely spans the test section so that the flow “sees” essentially an infinite wing. If the wing has a NACA 23012 airfoil section and a chord of 0.3 m, calculate the lift, drag, and moment about the