5.41

5.41 Water enters the horizontal, circular cross-sectional, sudden contraction nozzle sketched in Fig. P5.41 at section (1) with a uniformly distributed velocity of 25 ft/s and a pressure of 75 psi. The water exits from the nozzle into the atmosphere at section (2) where the uniformly distributed velocity is 100 ft/s. Determine the axial component of the anchoring force required to hold the contraction in place.

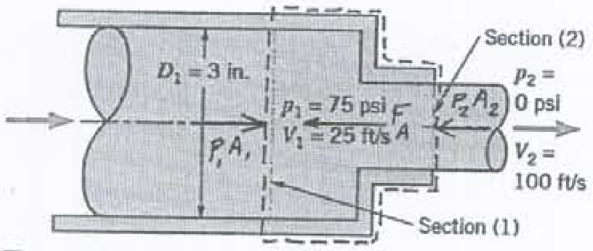

FIGURE P5.41

For this problem we include in the control volume the nozzle as well as the water at an instant between sections (1) and (2) as indicated in the sketch above. The horizontal forces acting on the contents of the control volume are shown in the sketch. Note that the atmospheric forces cancel out and are not shown. Application of the horizontal or x-direction component of the linear momentum equation (Eq. 5.22) to the flow through this control volume yields

$$-u_1 \rho u_1 A_1 + u_2 \rho u_2 A_2 = P_1 A_1 - F_A - P_2 A_2 \qquad (1)$$

From the conservation of mass equation (Eq. 5.12) we obtain

$$\dot{m} = \rho u_1 A_1 = \rho u_2 A_2$$

Thus Eq. (1) may be expessed as

$$\dot{m}(u_2 - u_1) = P_1 A_1 - F_A - P_2 A_2$$

or

$$F_A = P_1 A_1 - P_2 A_2 + \dot{m}(u_2 - u_1) = P_1 \frac{\pi D_1^2}{4} - P_2 \frac{\pi D_2^2}{4} - \rho u_1 \frac{\pi D_1^2}{4}(u_2 - u_1)$$

and

$$F_A = \left(75 \frac{lb}{in^2}\right) \frac{\pi (3 in.)^2}{4} - 0\,lb - \left(1.94 \frac{slugs}{ft^3}\right)\left(25 \frac{ft}{s}\right) \frac{\pi (3 in.)^2}{4\left(144 \frac{in.^2}{ft^2}\right)} \left(100 \frac{ft}{s} - 25 \frac{ft}{s}\right)\left(1 \frac{lb \cdot s^2}{slug \cdot ft}\right)$$

$$F_A = \underline{\underline{352}}\ lb$$