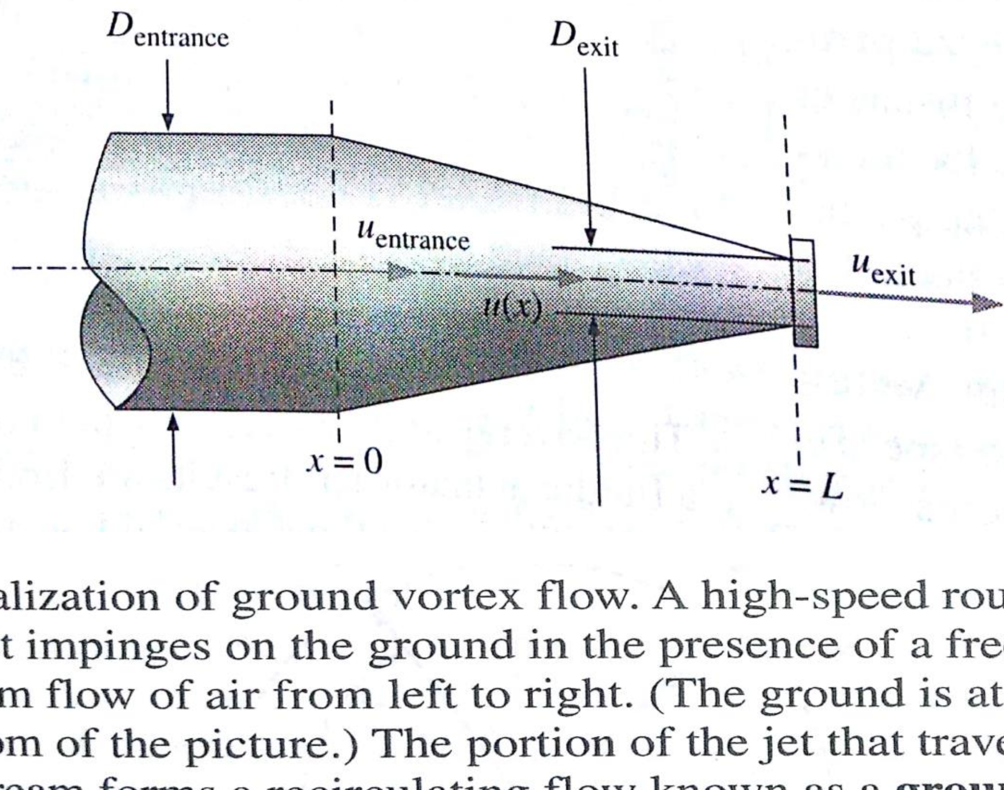
4–1C What does the word *kinematics* mean? Explain what the study of *fluid kinematics* involves.

4–2 Consider steady flow of water through an axisymmetric garden hose nozzle (Fig. P4–2). Along the centerline of the nozzle, the water speed increases from $u_{entrance}$ to u_{exit} as sketched. Measurements reveal that the centerline water speed increases parabolically through the nozzle. Write an equation for centerline speed $u(x)$, based on the parameters given here, from $x = 0$ to $x = L$.



Visualization of ground vortex flow. A high-speed round air jet impinges on the ground in the presence of a free-stream flow of air from left to right. (The ground is at the bottom of the picture.) The portion of the jet that travels upstream forms a recirculating flow known as a **ground vortex.** The visualization is produced by a smoke wire mounted vertically to the left of the field of view.

Photo by John M. Cimbala.

4–33 Converging duct flow (Fig. P4–16) is modeled by the steady, two-dimensional velocity field of Prob. 4–16. Generate an analytical expression for the flow streamlines.

Answer: $y = C/(U_0 + bx)$

4–34 Consider the following steady, incompressible, two-dimensional velocity field:

$$\vec{V} = (u, v) = (4.35 + 0.656x)\vec{i} + (-1.22 - 0.656y)\vec{j}$$

Generate an analytical expression for the flow streamlines and draw several streamlines in the upper-right quadrant from $x = 0$ to 5 and $y = 0$ to 6.

4–35 Consider the steady, incompressible, two-dimensional velocity field of Prob. 4–34. Generate a velocity vector plot in the upper-right quadrant from $x = 0$ to 5 and $y = 0$ to 6.

4–36 Consider the steady, incompressible, two-dimensional velocity field of Prob. 4–34. Generate a vector plot of the acceleration field in the upper-right quadrant from $x = 0$ to 5 and $y = 0$ to 6.

4–37 A steady, incompressible, two-dimensional velocity field is given by

$$\vec{V} = (u, v) = (1 + 2.5x + y)\vec{i} + (-0.5 - 3x - 2.5y)\vec{j}$$

where the x- and y-coordinates are in m and the magnitude of velocity is in m/s.

(*a*) Determine if there are any stagnation points in this flow field, and if so, where they are.

Bernoulli Equation

5–23C What is streamwise acceleration? How does it differ from normal acceleration? Can a fluid particle accelerate in steady flow?

5–24C Express the Bernoulli equation in three different ways using (*a*) energies, (*b*) pressures, and (*c*) heads.

5–25C What are the three major assumptions used in the derivation of the Bernoulli equation?

5–26C Define static, dynamic, and hydrostatic pressure. Under what conditions is their sum constant for a flow stream?

5–27C What is stagnation pressure? Explain how it can be measured.

5–28C Define pressure head, velocity head, and elevation head for a fluid stream and express them for a fluid stream whose pressure is P, velocity is V, and elevation is z.

5–29C What is the hydraulic grade line? How does it differ from the energy grade line? Under what conditions do both lines coincide with the free surface of a liquid?

5–30C How is the location of the hydraulic grade line determined for open-channel flow? How is it determined at the outlet of a pipe discharging to the atmosphere?

5–31C In a certain application, a siphon must go over a high wall. Can water or oil with a specific gravity of 0.8 go over a higher wall? Why?

5–32C Explain how and why a siphon works. Someone proposes siphoning cold water over a 7-m-high wall. Is this feasible? Explain.

5–33C A glass manometer with oil as the working fluid is connected to an air duct as shown in Fig. P5–33C. Will the

5–35C The water level of a tank on a building roof is 20 m above the ground. A hose leads from the tank bottom to the ground. The end of the hose has a nozzle, which is pointed straight up. What is the maximum height to which the water could rise? What factors would reduce this height?

5–36C A student siphons water over a 8.5-m-high wall at sea level. She then climbs to the summit of Mount Shasta (elevation 4390 m, P_{atm} = 58.5 kPa) and attempts the same experiment. Comment on her prospects for success.

5–37 In a hydroelectric power plant, water enters the turbine nozzles at 800 kPa absolute with a low velocity. If the nozzle outlets are exposed to atmospheric pressure of 100 kPa, determine the maximum velocity to which water can be accelerated by the nozzles before striking the turbine blades.

5–38 A Pitot-static probe is used to measure the speed of an aircraft flying at 3000 m. If the differential pressure reading is 3 kPa, determine the speed of the aircraft.

5–39 While traveling on a dirt road, the bottom of a car hits a sharp rock and a small hole develops at the bottom of its gas tank. If the height of the gasoline in the tank is 40 cm, determine the initial velocity of the gasoline at the hole. Discuss how the velocity will change with time and how the flow will be affected if the lid of the tank is closed tightly. *Answer:* 2.80 m/s below the bottom of the bottle. If the water level in the bottle is 0.45 m when it is full, determine how long it will take at the minimum to fill a 0.25-L glass (*a*) when the bottle is first opened and (*b*) when the bottle is almost empty. Neglect frictional losses.

5–41 A piezometer and a Pitot tube are tapped into a 4-cm-diameter horizontal water pipe, and the height of the water columns are measured to be 26 cm in the piezometer and 35 cm in the Pitot tube (both measured from the top surface of the pipe). Determine the velocity at the center of the pipe.

5–42 The diameter of a cylindrical water tank is D_o and its height is H. The tank is filled with water, which is open to the atmosphere. An orifice of diameter D with a smooth entrance (i.e., negligible losses) is open at the bottom. Develop a relation for the time required for the tank (*a*) to empty halfway and (*b*) to empty completely.

5–43 A siphon pumps water from a large reservoir to a lower tank that is initially empty. The tank also has a rounded orifice 6 m below the reservoir surface where the water leaves the tank. Both the siphon and the orifice diameters are 5 cm. Ignoring frictional losses, determine to what height the water will rise in the tank at equilibrium.

5–44 Water enters a tank of diameter D_T steadily at a mass flow rate of $\dot{m}_{in}$. An orifice at the bottom with diameter D_o allows water to escape. The orifice has a rounded entrance, so the frictional losses are negligible. If the tank is initially empty, (*a*) determine the maximum height that the water will reach in the tank and (*b*) obtain a relation for water height z as a function of time.

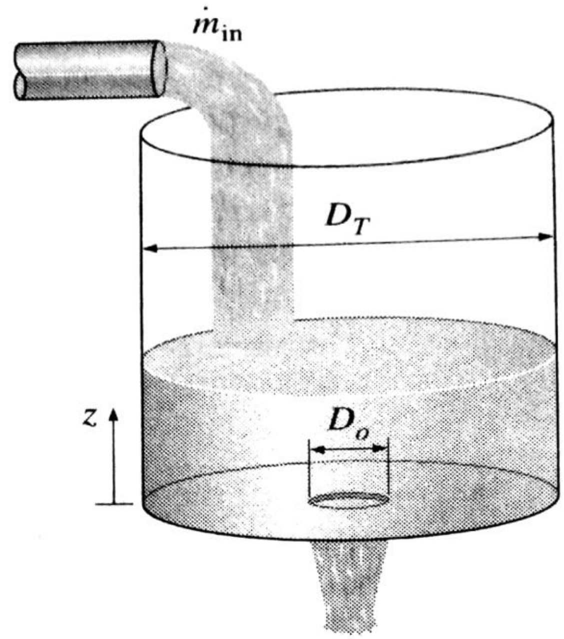


FIGURE P5–44

5–45 An airplane is flying at an altitude of 12,000 m. Determine the gage pressure at the stagnation point on the nose of the plane if the speed of the plane is 300 km/h. How would you solve this problem if the speed were 1050 km/h? Explain.

5–46 The air velocity in the duct of a heating system is to be measured by a Pitot-static probe inserted into the duct parallel to the flow. If the differential height between the water columns connected to the two outlets of the probe is 2.4 cm, determine (*a*) the flow velocity and (*b*) the pressure rise at the tip of the probe. The air temperature and pressure in the duct are 45°C and 98 kPa, respectively.

5–47 The water in a 8-m-diameter, 3-m-high aboveground swimming pool is to be emptied by unplugging a 3-cm-diameter, 25-m-long horizontal pipe attached to the bottom of the pool. Determine the maximum discharge rate of water through the pipe. Also, explain why the actual flow rate will be less.

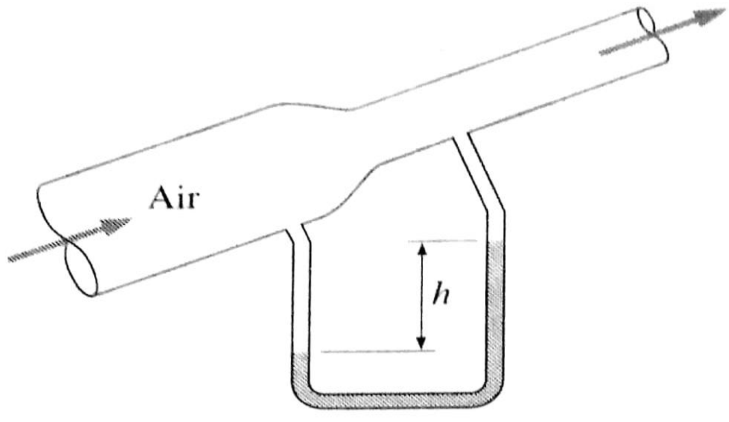


FIGURE P5–50

on the pipe where the two arms of the manometer are attached is 0.20 m. Determine the differential height between the fluid levels of the two arms of the manometer.

5–51 Air is flowing through a venturi meter whose diameter is 6.6 cm at the entrance part (location 1) and 4.6 cm at the throat (location 2). The gage pressure is measured to be 84 kPa at the entrance and 81 kPa at the throat. Neglecting frictional effects, show that the volume flow rate can be expressed as

$$\dot{V} = A_2\sqrt{\frac{2(P_1 - P_2)}{\rho(1 - A_2^2/A_1^2)}}$$

and determine the flow rate of air. Take the air density to be 1.2 kg/m³.

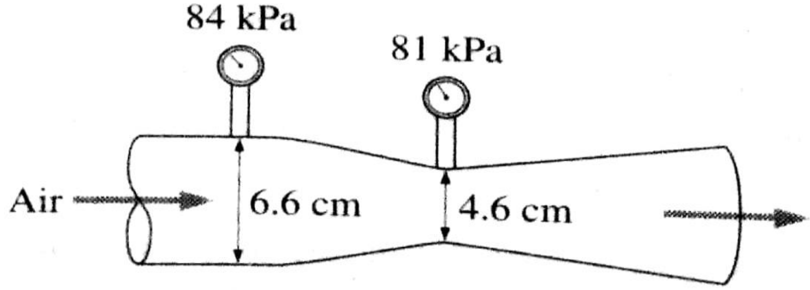


FIGURE P5–51

5–55 A handheld bicycle pump can be used as an atomizer to generate a fine mist of paint or pesticide by forcing air at a high velocity through a small hole and placing a short tube between the liquid reservoir and the high-speed air jet. The pressure across a subsonic jet exposed to the atmosphere is nearly atmospheric, and the surface of the liquid in the reservoir is also open to atmospheric pressure. In light of this, explain how the liquid is sucked up the tube. *Hint:* Read Sec. 5-4 carefully.

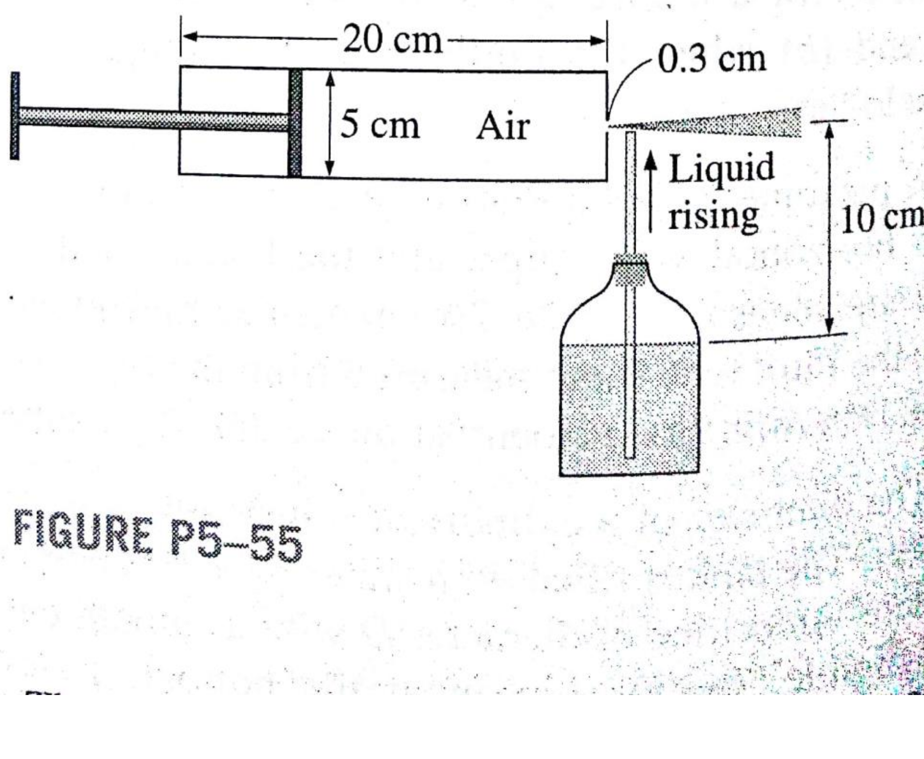


FIGURE P5–55

6–6C Explain the importance of the Reynolds transport theorem in fluid mechanics, and describe how the linear momentum equation is obtained from it.

6–7C What is the importance of the momentum-flux correction factor in the momentum analysis of flow systems? For which type(s) of flow is it significant and must it be considered in analysis: laminar flow, turbulent flow, or jet flow?

6–8C Write the momentum equation for steady one-dimensional flow for the case of no external forces and explain the physical significance of its terms.

6–9C In the application of the momentum equation, explain why we can usually disregard the atmospheric pressure and work with gage pressures only.

6–10C A rocket in space (no friction or resistance to motion) can expel gases relative to itself at some high velocity V. Is V the upper limit to the rocket's ultimate velocity?

6–11C Describe in terms of momentum and airflow how a helicopter is able to hover.

6–17C A horizontal water jet of constant velocity V from a stationary nozzle impinges normally on a vertical flat plate that rides on a nearly frictionless track. As the water jet hits the plate, it begins to move due to the water force. What is the highest velocity the plate can attain? Explain.

6–18 A horizontal water jet of constant velocity V impinges normally on a vertical flat plate and splashes off the sides in the vertical plane. The plate is moving toward the oncoming water jet with velocity $\frac{1}{2}V$. If a force F is required to maintain the plate stationary, how much force is required to move the plate toward the water jet?

the elbow in place. Take the momentum-flux correction factor to be 1.03 at both the inlet and the outlet.

6–20 Repeat Prob. 6–19 for the case of another (identical) elbow attached to the existing elbow so that the fluid makes a U-turn. *Answers: (a) 7.85 kPa, (b) 298 N*

6–21 A reducing elbow in a horizontal pipe is used to deflect water flow by an angle $\theta = 45°$ from the flow direction while accelerating it. The elbow discharges water into the atmosphere. The cross-sectional area of the elbow is 150 cm^2 at the inlet and 25 cm^2 at the exit. The elevation difference between the centers of the exit and the inlet is 40 cm. The mass of the elbow and the water in it is 50 kg. Determine the anchoring force needed to hold the elbow in place. Take the momentum-flux correction factor to be 1.03 at both the inlet and outlet.

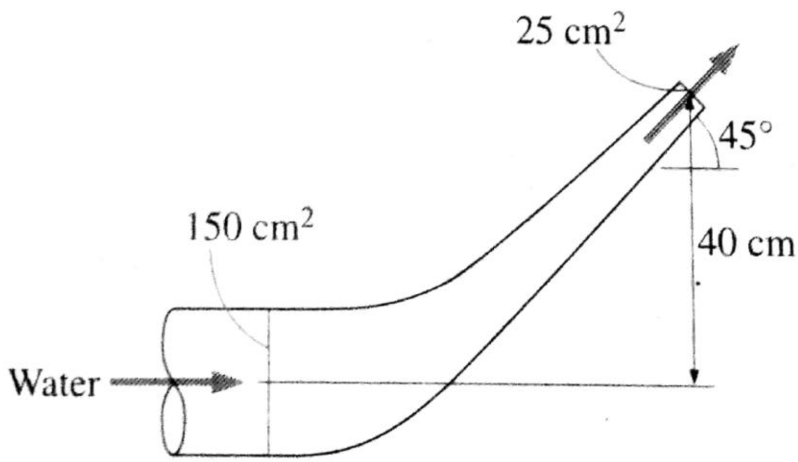


FIGURE P6–21

6–23 Water accelerated by a nozzle to 20 m/s strikes the vertical back surface of a cart moving horizontally at a constant velocity of 5 m/s in the flow direction. The mass flow rate of water through the stationary nozzle is 30 kg/s. After the strike, the water stream splatters off in all directions in the plane of the back surface. (*a*) Determine the force that needs to be applied by the brakes of the cart to prevent it from accelerating. (*b*) If this force were used to generate power instead of wasting it on the brakes, determine the maximum amount of power that could ideally be generated. *Answers:* (*a*) −338 N, (*b*) 1.69 kW

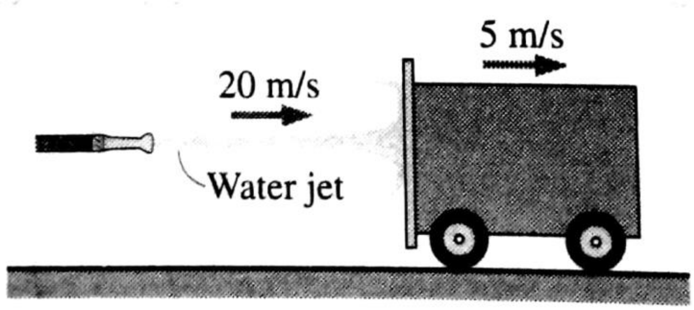


FIGURE P6–23

6–24 Reconsider Prob. 6–23. If the mass of the cart is 400 kg and the brakes fail, determine the acceleration of the cart when the water first strikes it. Assume the mass of water that wets the back surface is negligible.

6–27 A horizontal 5-cm-diameter water jet with a velocity of 18 m/s impinges normally upon a vertical plate of mass 1000 kg. The plate rides on a nearly frictionless track and is initially stationary. When the jet strikes the plate, the plate begins to move in the direction of the jet. The water always splatters in the plane of the retreating plate. Determine (*a*) the acceleration of the plate when the jet first strikes it (time = 0), (*b*) the time it takes for the plate to reach a velocity of 9 m/s, and (*c*) the plate velocity 20 s after the jet first strikes the plate. For simplicity, assume the velocity of the jet is increased as the cart moves such that the impulse force exerted by the water jet on the plate remains constant.

6–28 A 10-cm-diameter horizontal water jet having a velocity of 37 m/s strikes a curved plate, which deflects the water 180° at the same speed. Ignoring the frictional effects, determine the force required to hold the plate against the water stream.

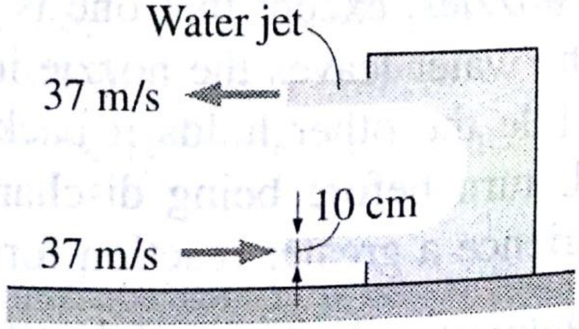


FIGURE P6–28

6–34 Reconsider the helicopter in Prob. 6–33, except that it is hovering on top of a 2800-m-high mountain where the air density is 0.928 kg/m^3. Noting that the unloaded helicopter blades must rotate at 400 rpm to hover at sea level, determine the blade rotational velocity to hover at the higher altitude. Also determine the percent increase in the required power input to hover at 3000-m altitude relative to that at sea level. *Answers:* 451 rpm, 12.8 percent

6–35 A sluice gate, which controls flow rate in a channel by simply raising or lowering a vertical plate, is commonly used in irrigation systems. A force is exerted on the gate due to the difference between the water heights y_1 and y_2 and the flow velocities V_1 and V_2 upstream and downstream from the gate, respectively. Take the width of the sluice gate (into the page) to be w. Wall shear stresses along the channel walls may be ignored, and for simplicity, we assume steady, uniform flow at locations 1 and 2. Develop a relationship for the force F_R acting on the sluice gate as a function of depths y_1 and y_2, mass flow rate $\dot{m}$, gravitational constant g, gate width w, and water density ρ.

6–36 Water enters a centrifugal pump axially at atmospheric pressure at a rate of 0.12 m^3/s and at a velocity of 7 m/s, and leaves in the normal direction along the pump casing, as shown in Fig. P6–36. Determine the force acting on the shaft (which is also the force acting on the bearing of the shaft) in the axial direction.

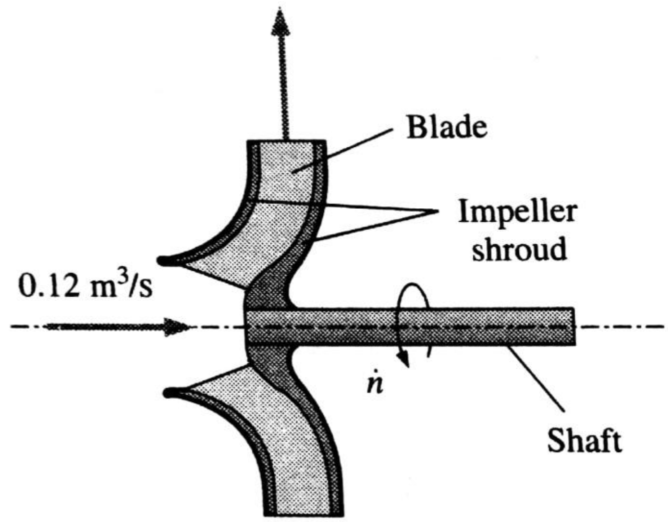


FIGURE P6–36

6–37 An incompressible fluid of density ρ and viscosity μ flows through a curved duct that turns the flow 180°. The duct cross-sectional area remains constant. The average velocity, momentum flux correction factor, and gage pressure are known at the inlet (1) and outlet (2), as in Fig. P6–37. (*a*) Write an expression for the horizontal force F_x of the fluid on the walls of the duct in terms of the given variables. (*b*) Verify your expression by plugging in the following values: ρ = 998.2 kg/m³, $\mu = 1.003 \times 10^{-3}$ kg/m · s, $A_1 = A_2 = 0.025$ m², $\beta_1 = 1.01$, $\beta_2 = 1.03$, $V_1 = 10$ m/s, $P_{1,\text{gage}} = 78.47$ kPa, and $P_{2,\text{gage}} = 65.23$ kPa. *Answer:* (*b*) F_x = 8680 N to the right