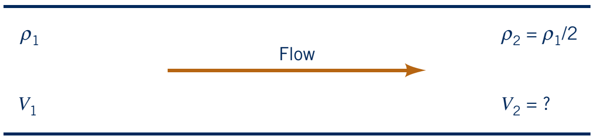
Review Problems

Go to Appendix G (*WileyPLUS* or the book's website, www.wiley.com/college/munson) for a set of review problems with answers. Detailed solutions can be found in the *Student Solution Manual and Study Guide for Fundamentals of Fluid Mechanics*, by Munson et al. (© 2013 John Wiley and Sons, Inc.).

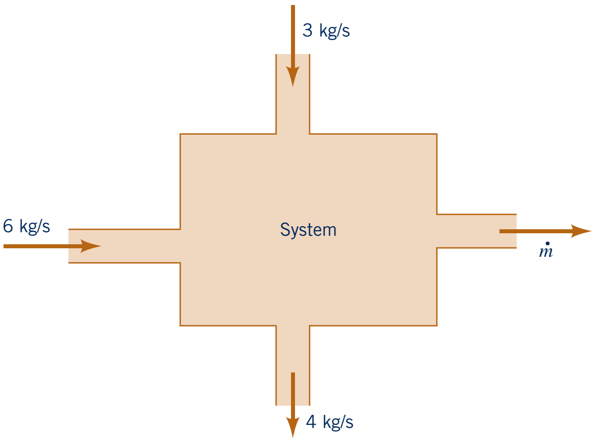
Conceptual Questions

5.1C A fluid flows steadily through a pipe with a uniform cross-sectional area. The density of the fluid decreases to half its initial value as it flows through the pipe. The correct statement about the average velocity V is



a) V_2 equals 2 V_1. b) V_2 equals $V_1/2$. c) V_2 equals V_1.
d) V_2 equals $V_1/4$. e) V_2 equals 4 V_1.

5.2C Water flows steadily into and out of the system with four pipes shown below. The mass flowrate through three of the pipes in kg/s is indicated.



The mass flowrate $\dot{m}$ in the fourth pipe is

a) 13 kg/s. b) 9 kg/s. c) 6 kg/s.
d) 5 kg/s. e) 4kg/s.

5.3C The nozzle on a fire hose is connected to the hose via a coupling. When the fire hose is in use with water flowing through it and the hose is stationary, the coupling is:

a) in equilibrium, so there is no force on the coupling.

b) in tension.

c) in compression.

5.4C Two fluid jets are pointed at surfaces as shown in the following figures. The fluids are incompressible, and the effects of gravity can be neglected. The mass flowrates and the velocities of the jets are identical. The cross-sectional areas of the jets do not change significantly as the fluid flows.

The correct statement regarding the horizontal forces is

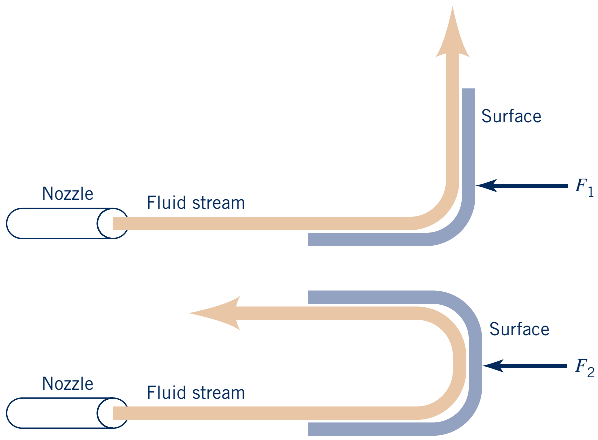
a) F_1 equals 2 F_2.

b) F_1 is greater than 0 and F_2 equals 0.

c) F_1 equals $F_2/2$.

d) F_1 equals 0 and F_2 is greater than 0.

e) F_1 equals F_2.



Additional conceptual questions are available in *WileyPLUS* at the instructor's discretion.

Problems

Note: Unless specific values of required fluid properties are given in the problem statement, use the values found in the tables on the inside of the front cover. Answers to the even-numbered problems are listed at the end of the book. The Lab Problems as well as the videos that accompany problems can be accessed in *WileyPLUS* or the book's website, www.wiley.com/college/munson.

Section 5.1.1 Derivation of the Continuity Equation

5.1 Use the Reynolds transport theorem (Eq. 4.19) with B = volume and, therefore, b = volume/mass = 1/density to obtain the continuity equation for steady or unsteady incompressible flow through a fixed control volume: $\int_{cv} \mathbf{V} \cdot \hat{\mathbf{n}} \, dA = 0$.

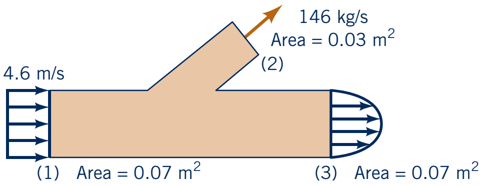
5.2 An incompressible fluid flows horizontally in the x–y plane with a velocity given by

$$u = 30(y/h)^{1/2} \text{ m/s}, \ v = 0$$

where y and h are in meters and h is a constant. Determine the average velocity for the portion of the flow between $y = 0$ and $y = h$.

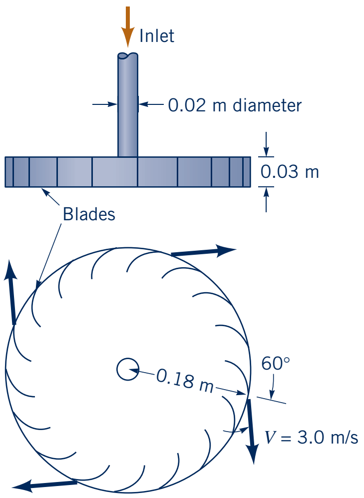
Section 5.1.2 Fixed, Nondeforming Control Volume—Uniform Velocity Profile or Average Velocity

5.3 Water flows steadily through the horizontal piping system shown in Fig. P5.3. The velocity is uniform at section (1), the mass flowrate is 146 kg/s at section (2), and the velocity is nonuniform at section (3). **(a)** Determine the value of the quantity $\frac{D}{Dt}\int_{sys} \rho d\forall$, where the system is the water contained in the pipe bounded by sections (1), (2), and (3). **(b)** Determine the mean velocity at section (2). **(c)** Determine, if possible, the value of the integral $\int_{(3)} \rho \mathbf{V} \cdot \hat{\mathbf{n}}\, dA$ over section (3). If it is not possible, explain what additional information is needed to do so.



■ Figure P5.3

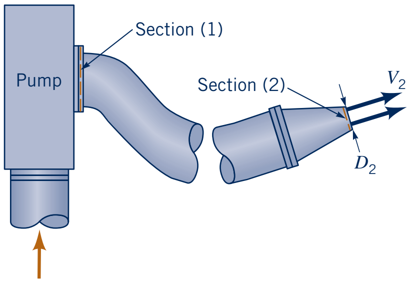
5.4 WILEY Water flows out through a set of thin, closely spaced blades as shown in Fig. P5.4 with a speed of $V = 3.0$ m/s around the entire circumference of the outlet. Determine the mass flowrate through the inlet pipe.



■ Figure P5.4

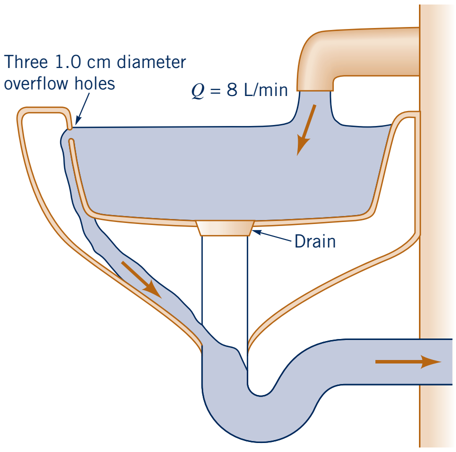
† **5.5** Estimate the rate (in L/h) that your car uses gasoline when it is being driven on an interstate highway. Determine how long it would take to empty a 360 ml soft-drink container at this flowrate. List all assumptions and show calculations.

5.6 WILEY The pump shown in Fig. P5.6 produces a steady flow of 40 L/min through the nozzle. Determine the nozzle exit diameter, D_2, if the exit velocity is to be $V_2 = 30$ m/s.



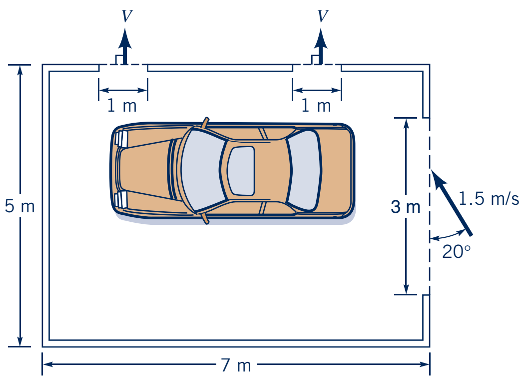
■ Figure P5.6

5.7 WILEY Water flows into a sink as shown in **Video V5.1** and Fig. P5.7 at a rate of 8 L/min. Determine the average velocity through each of the three 1.0 cm diameter overflow holes if the drain is closed and the water level in the sink remains constant.



■ Figure P5.7

5.8 The wind blows through a 2 m × 3 m garage door opening with a speed of 1.5 m/s as shown in Fig. P5.8. Determine the average speed, V, of the air through the two 1 m × 1.2 m openings in the windows.

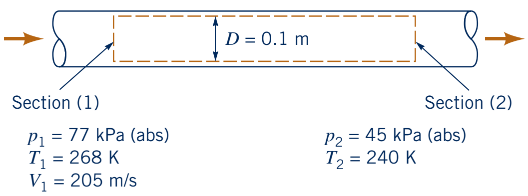


■ Figure P5.8

5.9 The human circulatory system consists of a complex branching pipe network ranging in diameter from the aorta (largest) to the capillaries (smallest). The average radii and the number of these vessels are shown in the table. Does the average blood velocity increase, decrease, or remain constant as it travels from the aorta to the capillaries?

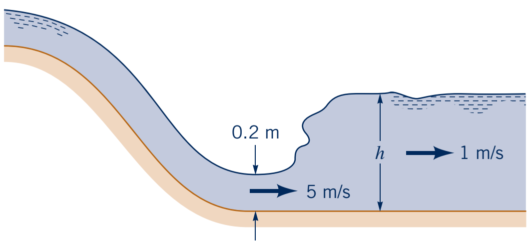
Vessel	Average Radius, mm	Number
Aorta	12.5	1
Arteries	2.0	159
Arterioles	0.03	1.4×10^7
Capillaries	0.006	3.9×10^9

5.10 Air flows steadily between two cross sections in a long, straight section of 0.1 m inside-diameter pipe. The static temperature and pressure at each section are indicated in Fig. P5.10. If the average air velocity at section (1) is 205 m/s, determine the average air velocity at section (2).



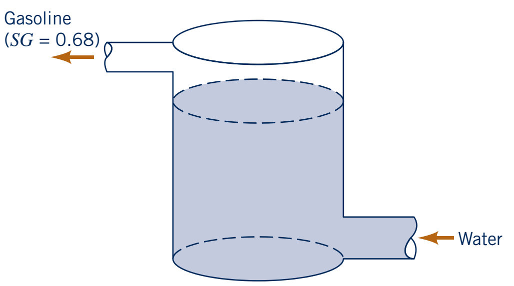
■ **Figure P5.10**

5.11 A hydraulic jump (see **Video V10.11**) is in place downstream from a spillway as indicated in Fig. P5.11. Upstream of the jump, the depth of the stream is 0.2 m and the average stream velocity is 5 m/s. Just downstream of the jump, the average stream velocity is 1 m/s. Calculate the depth of the stream, h, just downstream of the jump.



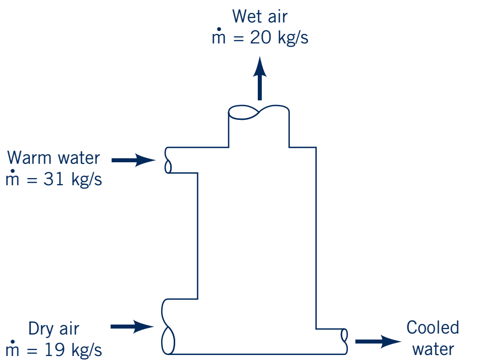
■ **Figure P5.11**

5.12 Water enters a rigid, sealed, cylindrical tank at a steady rate of 100 liters/h and forces gasoline ($SG = 0.68$) out as is indicated in Fig. P5.12. What is the time rate of change of mass of gasoline contained in the tank?



■ **Figure P5.12**

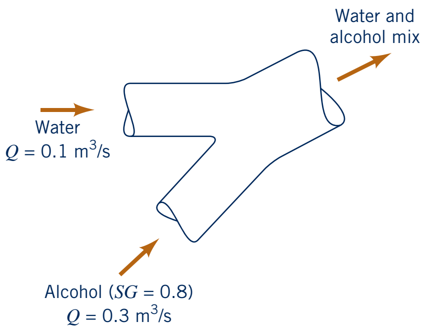
5.13 An evaporative cooling tower (see Fig. P5.13) is used to cool water from 43 °C to 27 °C. Water enters the tower at a rate of 31.0 kg/s. Dry air (no water vapor) flows into the tower at a rate of 19 kg/s. If the rate of wet airflow out of the tower is 20 kg/s, determine the rate of water evaporation in kg/s and the rate of cooled water flow in kg/s.



■ **Figure P5.13**

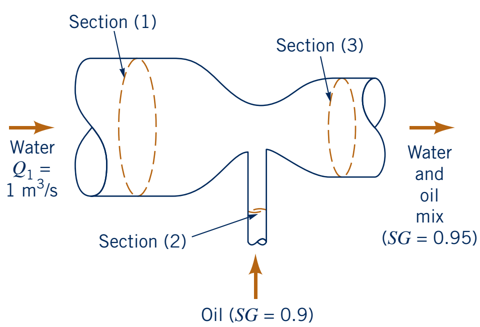
5.14 At cruise conditions, air flows into a jet engine at a steady rate of 30 kg/s. Fuel enters the engine at a steady rate of 0.3 kg/s. The average velocity of the exhaust gases is 500 m/s relative to the engine. If the engine exhaust effective cross-sectional area is 0.3 m^2 estimate the density of the exhaust gases in kg/m^3.

5.15 Water at 0.1 m^3/s and alcohol ($SG = 0.8$) at 0.3 m^3/s are mixed in a y-duct as shown in Fig. 5.15. What is the average density of the mixture of alcohol and water?



■ **Figure P5.15**

5.16 Oil having a specific gravity of 0.9 is pumped as illustrated in Fig. P5.16 with a water jet pump. The water volume flowrate is 1 m^3/s. The water and oil mixture has an average specific gravity of 0.95. Calculate the rate, in m^3/s, at which the pump moves oil.

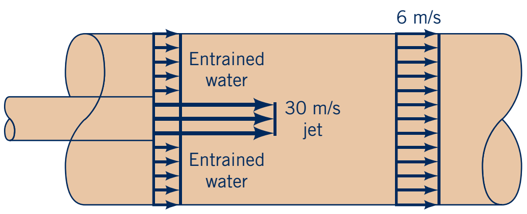


■ **Figure P5.16**

5.17 Fresh water flows steadily into an open 200 L drum initially filled with seawater. The fresh water mixes thoroughly with the seawater, and the mixture overflows out of the drum. If the fresh water flowrate is 40 L/min, estimate the time in seconds required to decrease the difference between the density of the mixture and the density of fresh water by 50%.

Section 5.1.2 Fixed, Nondeforming Control Volume—Nonuniform Velocity Profile

5.18 A water jet pump (see Fig. P5.18) involves a jet cross-sectional area of 0.01 m^2, and a jet velocity of 30 m/s. The jet is surrounded by entrained water. The total cross-sectional area associated with the jet and entrained streams is 0.075 m^2. These two fluid streams leave the pump thoroughly mixed with an average velocity of 6 m/s through a cross-sectional area of 0.075 m^2. Determine the pumping rate (i.e., the entrained fluid flowrate) involved in liters/s.

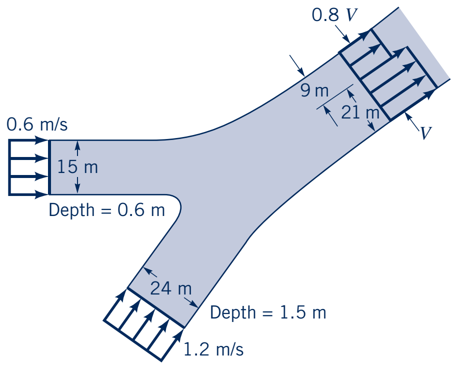


■ **Figure P5.18**

***5.19** To measure the mass flowrate of air through a 15 cm inside-diameter pipe, local velocity data are collected at different radii from the pipe axis (see Table). Determine the mass flowrate corresponding to the data listed in the following table.

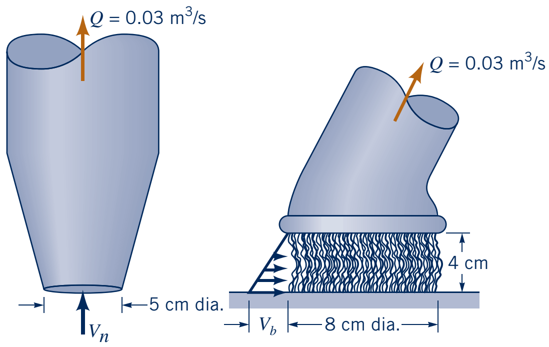
r (cm)	Axial Velocity (m/s)
0	9
0.5	9.05
1.0	8.95
1.5	8.85
2.0	8.75
2.5	8.62
3.0	8.50
3.5	8.36
4.0	8.19
4.5	8.02
5.0	7.81
5.5	7.57
6.0	7.26
6.5	6.85
7.0	6.21
7.4	5.62
7.5	5.09
7.6	4.46
7.6	0

5.20 Two rivers merge to form a larger river as shown in Fig. P5.20. At a location downstream from the junction (before the two streams completely merge), the nonuniform velocity profile is as shown and the depth is 1.8 m. Determine the value of V.



■ **Figure P5.20**

5.21 Various types of attachments can be used with the shop vac shown in **Video V5.2**. Two such attachments are shown in Fig. P5.21—a nozzle and a brush. The flowrate is 0.03 m^3/s. **(a)** Determine the average velocity through the nozzle entrance, V_n. **(b)** Assume the air enters the brush attachment in a radial direction all around the brush with a velocity profile that varies linearly from 0 to V_b along the length of the bristles as shown in the figure. Determine the value of V_b.



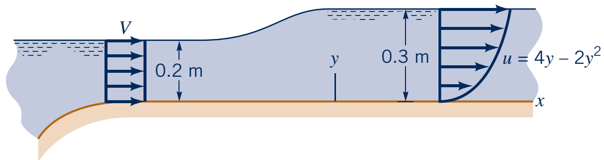
■ **Figure P5.21**

5.22 An appropriate turbulent pipe flow velocity profile is

$$\mathbf{V} = u_c\left(\frac{R - r}{R}\right)^{1/n}\hat{\mathbf{i}}$$

where u_c = centerline velocity, r = local radius, R = pipe radius, and $\hat{\mathbf{i}}$ = unit vector along pipe centerline. Determine the ratio of average velocity, $\bar{u}$, to centerline velocity, u_c, for **(a)** $n = 4$, **(b)** $n = 6$, **(c)** $n = 8$, **(d)** $n = 10$. Compare the different velocity profiles.

5.23 As shown in Fig. P5.23, at the entrance to a 1 m wide channel the velocity distribution is uniform with a velocity V. Further downstream the velocity profile is given by $u = 4y - 2y^2$, where u is in m/s and y is in m. Determine the value of V.

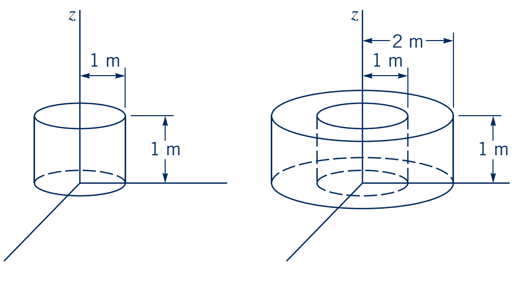


■ **Figure P5.23**

5.24 An incompressible flow velocity field (water) is given as

$$\mathbf{V} = -\frac{1}{r}\hat{\mathbf{e}}_r + \frac{1}{r}\hat{\mathbf{e}}_\theta \text{ m/s}$$

where r is in meters. **(a)** Calculate the mass flowrate through the cylindrical surface at $r = 1$ m from $z = 0$ to $z = 1$ m as shown in Fig. P5.24*a*. **(b)** Show that mass is conserved in the annular control volume from $r = 1$ m to $r = 2$ m and $z = 0$ to $z = 1$ m as shown in Fig. P5.24*b*.

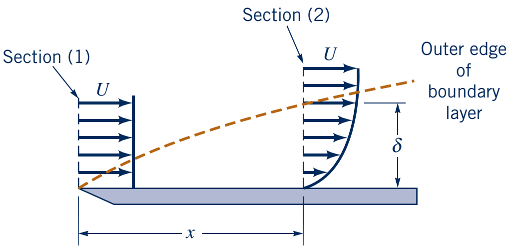


■ **Figure P5.24**

5.25 Flow of a viscous fluid over a flat plate surface results in the development of a region of reduced velocity adjacent to the wetted surface as depicted in Fig. P5.25. This region of reduced flow is called a boundary layer. At the leading edge of the plate, the velocity profile may be considered uniformly distributed with a value U. All along the outer edge of the boundary layer, the fluid velocity component parallel to the plate surface is also U. If the x-direction velocity profile at section (2) is

$$\frac{u}{U} = \left(\frac{y}{\delta}\right)^{1/7}$$

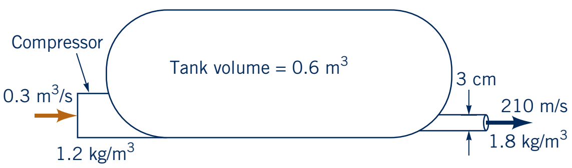
develop an expression for the volume flowrate through the edge of the boundary layer from the leading edge to a location downstream at x where the boundary layer thickness is δ.



■ **Figure P5.25**

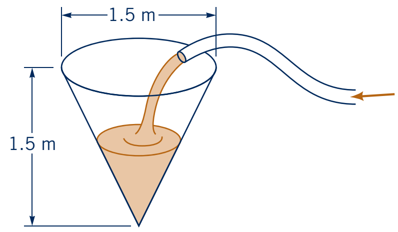
Section 5.1.2 Fixed, Nondeforming Control Volume—Unsteady Flow

5.26 Air at standard conditions enters the compressor shown in Fig. P5.26 at a rate of 0.3 m^3/s. It leaves the tank through a 3 cm diameter pipe with a density of 1.8 kg/m^3 and a uniform speed of 210 m/s. **(a)** Determine the rate (kg/s) at which the mass of air in the tank is increasing or decreasing. **(b)** Determine the average time rate of change of air density within the tank.



■ **Figure P5.26**

5.27 Estimate the time required to fill with water a cone-shaped container (see Fig. P5.27) 1.5 m high and 1.5 m across at the top if the filling rate is 76 L/min.



■ **Figure P5.27**

5.28 How long would it take to fill a cylindrical-shaped swimming pool having a diameter of 8 m to a depth of 1.5 m with water from a garden hose if the flowrate is 1.0 liter/s?

Section 5.1.3 Moving, Nondeforming Control Volume

†5.29 For an automobile moving along a highway, describe the control volume you would use to estimate the flowrate of air across the radiator. Explain how you would estimate the velocity of that air.

Section 5.1.4 Deforming Control Volume

5.30 A hypodermic syringe (see Fig. P5.30) is used to apply a vaccine. If the plunger is moved forward at the steady rate of 20 mm/s and if vaccine leaks past the plunger at 0.1 of the volume flowrate out the needle opening, calculate the average velocity of the needle exit flow. The inside diameters of the syringe and the needle are 20 mm and 0.7 mm.

■ **Figure P5.30**

5.31 The Hoover Dam (see **Video V2.4**) backs up the Colorado River and creates Lake Mead, which is approximately 185 km long and has a surface area of approximately 580 square kilometers. If during flood conditions the Colorado River flows into the lake at a rate of 1300 m^3/s and the outflow from the dam is 227 m^3/s, how many meters per 24-hour day will the lake level rise?

5.32 Storm sewer backup causes your basement to flood at the steady rate of 2.5 cm of depth per hour. The basement floor area is 139 m^2. What capacity (L/min) pump would you rent to **(a)** keep the water accumulated in your basement at a constant level until the storm sewer is blocked off, and **(b)** reduce the water accumulation in your basement at a rate of 7.5 cm/h even while the backup problem exists?

5.33 (See Fluids in the News article **"New 6 LPF standards,"** Section 5.1.2.) When a toilet is flushed, the water depth, h, in the tank as a function of time, t, is as given in the table. The size of the rectangular tank is 50 cm by 20 cm. **(a)** Determine the volume of water used per flush, liter per flush. **(b)** Plot the flowrate for $0 \leq t \leq 6$ s.

t (s)	h (cm)
0	14.5
0.5	13.5
1.0	12.1
2.0	8.8
3.0	6.1
4.0	3.8
5.0	1.9
6.0	0

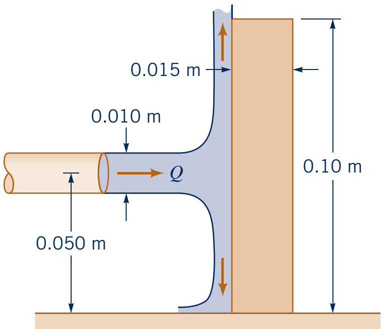
Section 5.2.1 Derivation of the Linear Momentum Equation

5.34 A fluid flows steadily in the x direction through a control volume. Measurements indicate that to cause this flow the force acting on the contents of the control volume is 120 N in the negative x direction. Determine the net rate of flow of linear momentum through the control surface.

5.35 Consider the unsteady flow of a fluid in the x direction through a control volume. The linear momentum of the fluid within the control volume is a function of time given by $890\, t\, \hat{\mathbf{i}}$ kg · m/s, where t is in seconds and $\hat{\mathbf{i}}$ is a unit vector in the x direction. Measurements indicate that to cause this flow the force acting on the contents of the control volume is $178\, \hat{\mathbf{i}}$ N. Determine the net rate of flow of linear momentum through the control surface.

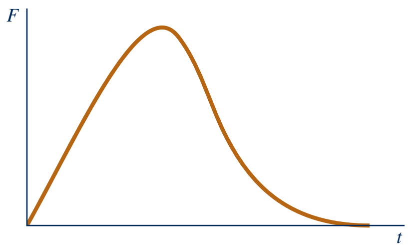
Section 5.2.2 Application of the Linear Momentum Equation (also see Lab Problems 5.1LP, 5.2LP, 5.3LP, and 5.4LP)

5.36 A 10 mm diameter jet of water is deflected by a homogeneous rectangular block (15 mm by 200 mm by 100 mm) that weighs 6 N as shown in **Video V5.6** and Fig. P5.36. Determine the minimum volume flowrate needed to tip the block.



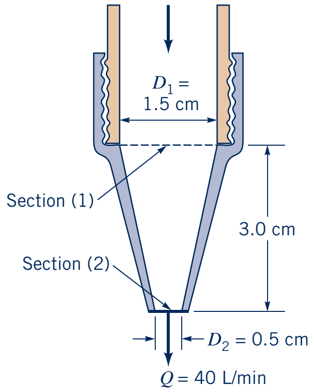
■ **Figure P5.36**

†5.37 When a baseball player catches a ball, the force of the ball on her glove is as shown as a function of time in Fig. P5.37. Describe how this situation is similar to the force generated by the deflection of a jet of water by a vane. *Note:* Consider many baseballs being caught in quick succession.



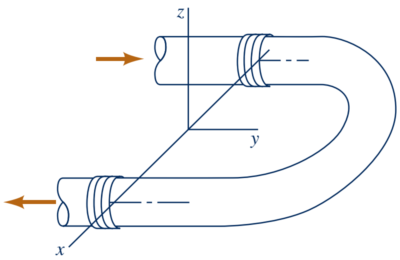
■ **Figure P5.37**

5.38 Determine the anchoring force required to hold in place the conical nozzle attached to the end of the laboratory sink faucet shown in Fig. P5.38 when the water flowrate is 40 L/min. The nozzle weight is 1 N. The nozzle inlet and exit inside diameters are 1.5 cm and 0.5 cm, respectively. The nozzle axis is vertical, and the axial distance between sections (1) and (2) is 3 cm. The pressure at section (1) is 470 kPa.



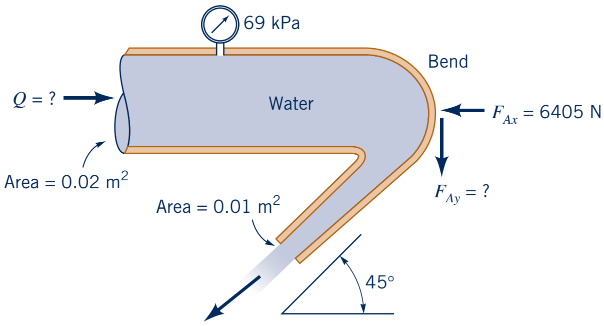
■ **Figure P5.38**

5.39 Water flows through a horizontal, 180° pipe bend as is illustrated in Fig. P5.39. The flow cross-sectional area is constant at a value of 9000 mm^2. The flow velocity everywhere in the bend is 15 m/s. The pressures at the entrance and exit of the bend are 210 and 165 kPa, respectively. Calculate the horizontal (x and y) components of the anchoring force needed to hold the bend in place.



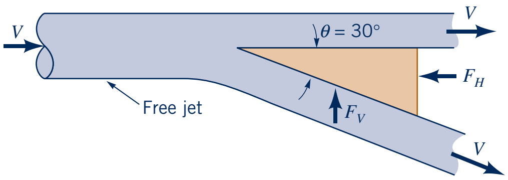
■ **Figure P5.39**

5.40 Water flows through a horizontal bend and discharges into the atmosphere as shown in Fig. P5.40. When the pressure gage reads 69 kPa, the resultant x-direction anchoring force, F_{Ax}, in the horizontal plane required to hold the bend in place is shown on the figure. Determine the flowrate through the bend and the y-direction anchoring force, F_{Ay}, required to hold the bend in place. The flow is not frictionless.



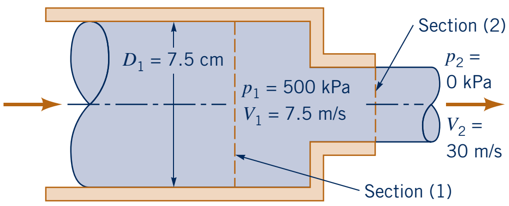
■ **Figure P5.40**

5.41 A free jet of fluid strikes a wedge as shown in Fig. P5.41. Of the total flow, a portion is deflected 30°; the remainder is not deflected. The horizontal and vertical components of force needed to hold the wedge stationary are F_H and F_V, respectively. Gravity is negligible, and the fluid speed remains constant. Determine the force ratio, F_H/F_V.



■ **Figure P5.41**

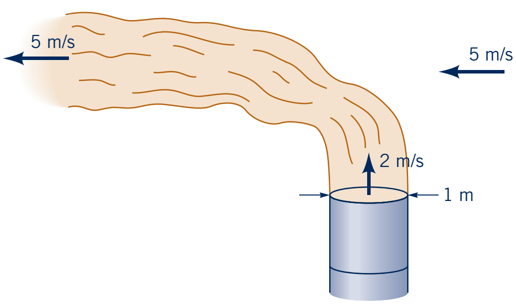
5.42 WILEY Water enters the horizontal, circular cross-sectional, sudden contraction nozzle sketched in Fig. P5.42 at section (1) with a uniformly distributed velocity of 7.5 m/s and a pressure of 500 kPa. The water exits from the nozzle into the atmosphere at section (2) where the uniformly distributed velocity is 30 m/s. Determine the axial component of the anchoring force required to hold the contraction in place.



■ **Figure P5.42**

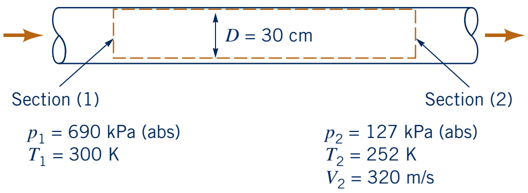
†5.43 A truck carrying chickens is too heavy for a bridge that it needs to cross. The empty truck is within the weight limits; with the chickens it is overweight. It is suggested that if one could get the chickens to fly around the truck (i.e., by banging on the truck's side) it would be safe to cross the bridge. Do you agree? Explain.

5.44 WILEY Exhaust (assumed to have the properties of standard air) leaves the 1 m diameter chimney shown in **Video V5.4** and Fig. P5.44 with a speed of 2 m/s. Because of the wind, after a few diameters downstream the exhaust flows in a horizontal direction with the speed of the wind, 5 m/s. Determine the horizontal component of the force that the blowing wind exerts on the exhaust gases.



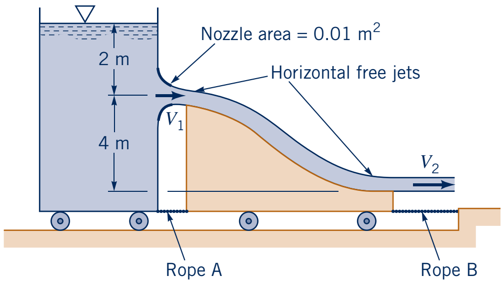
■ **Figure P5.44**

5.45 Air flows steadily between two cross sections in a long, straight section on 30 cm inside-diameter pipe. The static temperature and pressure at each section are indicated in Fig P5.45. If the average air velocity at section (2) is 320 m/s, determine the average air velocity at section (1). Determine the frictional force exerted by the pipe wall on the air flowing between sections (1) and (2). Assume uniform velocity distributions at each section.



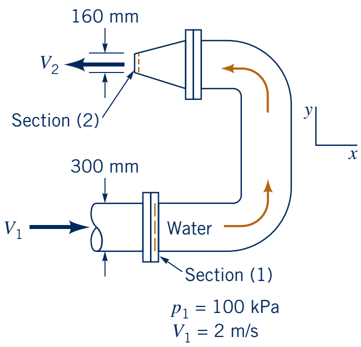
■ **Figure P5.45**

5.46 Water flows steadily from a tank mounted on a cart as shown in Fig. 5.46. After the water jet leaves the nozzle of the tank, it falls and strikes a vane attached to another cart. The cart's wheels are frictionless, and the fluid is inviscid. **(a)** Determine the speed of the water leaving the tank, V_1, and the water speed leaving the cart, V_2. **(b)** Determine the tension in rope *A*. **(c)** Determine the tension in rope *B*.



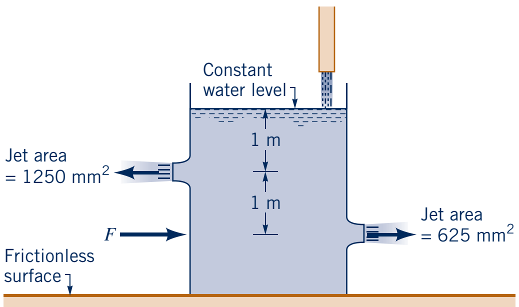
■ **Figure P5.46**

5.47 WILEY Determine the magnitude and direction of the anchoring force needed to hold the horizontal elbow and nozzle combination shown in Fig. P5.47 in place. Atmospheric pressure is 100 kPa(abs). The gage pressure at section (1) is 100 kPa. At section (2), the water exits to the atmosphere.



■ **Figure P5.47**

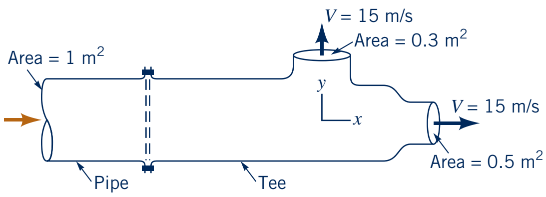
5.48 Water is added to the tank shown in Fig. P5.48 through a vertical pipe to maintain a constant (water) level. The tank is placed



■ **Figure P5.48**

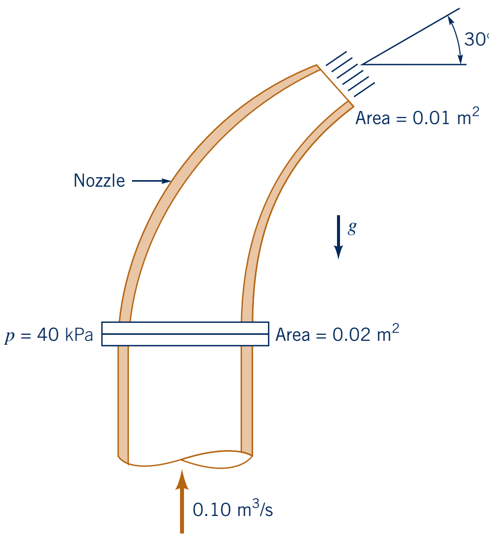
on a horizontal plane which has a frictionless surface. Determine the horizontal force, F, required to hold the tank stationary. Neglect all losses.

5.49 WILEY GO Water flows as two free jets from the tee attached to the pipe shown in Fig. P5.49. The exit speed is 15 m/s. If viscous effects and gravity are negligible, determine the x and y components of the force that the pipe exerts on the tee.



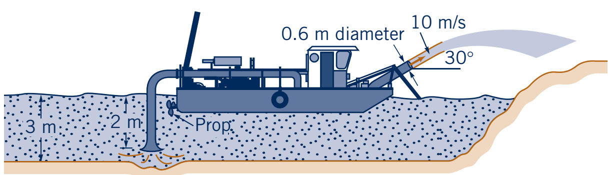
■ **Figure P5.49**

5.50 A nozzle is attached to a vertical pipe and discharges water into the atmosphere as shown in Fig. P5.50. When the discharge is 0.1 m^3/s, the gage pressure at the flange is 40 kPa. Determine the vertical component of the anchoring force required to hold the nozzle in place. The nozzle has a weight of 200 N, and the volume of water in the nozzle is 0.012 m^3. Is the anchoring force directed upward or downward?



■ **Figure P5.50**

5.51 WILEY GO The hydraulic dredge shown in Fig. P5.51 is used to dredge sand from a river bottom. Estimate the thrust needed from the propeller to hold the boat stationary. Assume the specific gravity of the sand/water mixture is $SG = 1.4$.



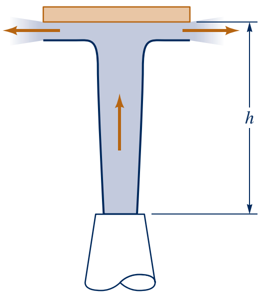
■ **Figure P5.51**

5.52 WILEY GO A static thrust stand is to be designed for testing a specific jet engine, knowing the following conditions for a typical test.

intake air velocity = 210 m/s
exhaust gas velocity = 500 m/s
intake cross section area = 1 m^2
intake static pressure = 79 kPa
intake static temperature = 267 K
exhaust gas pressure = 0 kPa

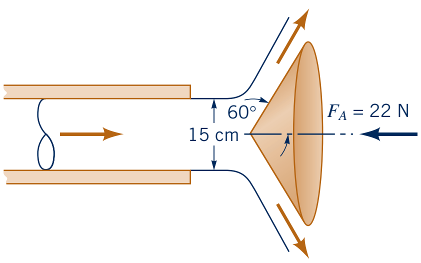
estimate a nominal thrust to design for.

5.53 A vertical jet of water leaves a nozzle at a speed of 10 m/s and a diameter of 20 mm. It suspends a plate having a mass of 1.5 kg as indicated in Fig. P5.53. What is the vertical distance h?



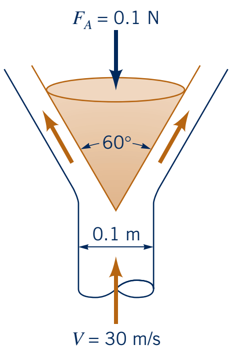
■ **Figure P5.53**

5.54 WILEY GO A horizontal, circular cross-sectional jet of air having a diameter of 15 cm strikes a conical deflector as shown in Fig. P5.54. A horizontal anchoring force of 22 N is required to hold the cone in place. Estimate the nozzle flowrate in m^3/s. The magnitude of the velocity of the air remains constant.



■ **Figure P5.54**

5.55 WILEY GO A vertical, circular cross-sectional jet of air strikes a conical deflector as indicated in Fig. P5.55. A vertical anchoring force of 0.1 N is required to hold the deflector in place. Determine the mass (kg) of the deflector. The magnitude of velocity of the air remains constant.



■ **Figure P5.55**

5.56 A vertical jet of water having a nozzle exit velocity of 4.5 m/s with a diameter of 2.5 cm suspends a hollow hemisphere as indicated in Fig. P5.56. If the hemisphere is stationary at an elevation of 30 cm, determine its weight.

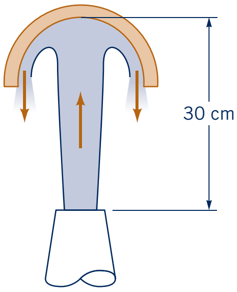


Figure P5.56

5.57 Air flows into the atmosphere from a nozzle and strikes a vertical plate as shown in Fig. P5.57. A horizontal force of 12 N is required to hold the plate in place. Determine the reading on the pressure gage. Assume the flow to be incompressible and frictionless.

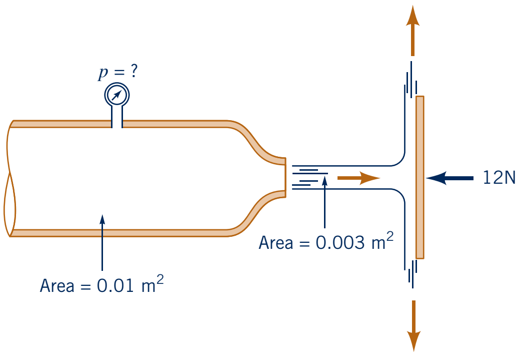


Figure P5.57

5.58 WILEY Water flows from a large tank into a dish as shown in Fig. P5.58. **(a)** If at the instant shown the tank and the water in it weigh W_1 N, what is the tension, T_1, in the cable supporting the tank? **(b)** If at the instant shown the dish and the water in it weigh W_2 N, what is the force, F_2, needed to support the dish?

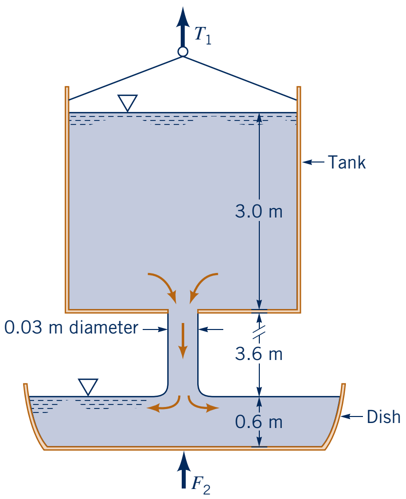


Figure P5.58

5.59 WILEY Two water jets of equal size and speed strike each other as shown in Fig. P5.59. Determine the speed, V, and direction, θ, of the resulting combined jet. Gravity is negligible.

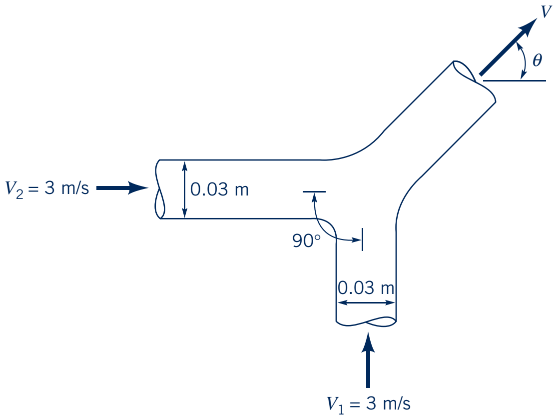


Figure P5.59

5.60 WILEY GO Assuming frictionless, incompressible, one-dimensional flow of water through the horizontal tee connection sketched in Fig. P5.60, estimate values of the x and y components of the force exerted by the tee on the water. Each pipe has an inside diameter of 1 m.

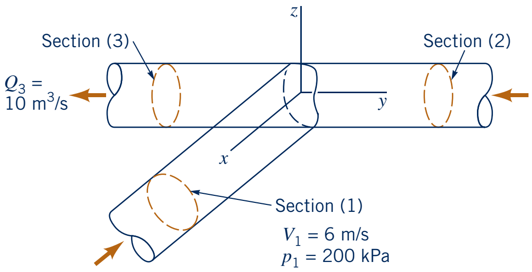


Figure P5.60

5.61 Water discharges into the atmosphere through the device shown in Fig. P5.61. Determine the x component of force at the flange required to hold the device in place. Neglect the effect of gravity and friction.

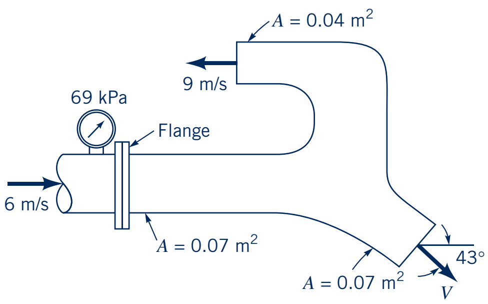
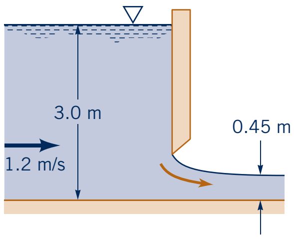


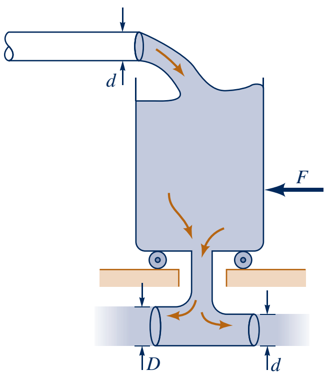
Figure P5.61

5.62 WILEY Determine the magnitude of the horizontal component of the anchoring force required to hold in place the sluice gate shown in Fig. 5.62. Compare this result with the size of the horizontal component of the anchoring force required to hold in place the sluice gate when it is closed and the depth of water upstream is 3 m.



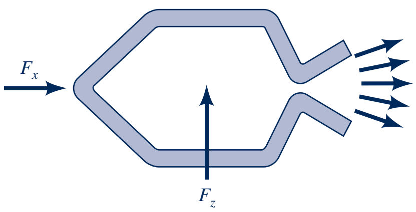
■ **Figure P5.62**

5.63 Water flows steadily into and out of a tank that sits on frictionless wheels as shown in Fig. P5.63. Determine the diameter D so that the tank remains motionless if $F = 0$.



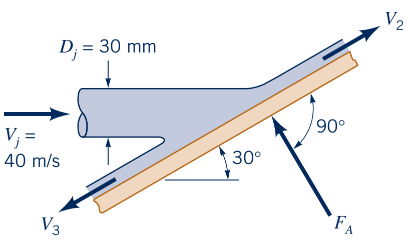
■ **Figure P5.63**

5.64 The rocket shown in Fig. P5.64, is held stationary by the horizontal force, F_x, and the vertical force, F_z. The velocity and pressure of the exhaust gas are 1500 m/s and 138 kPa at the nozzle exit, which has a cross section area of 390 cm^2. The exhaust mass flowrate is constant at 10 kg/s. Determine the value of the restraining force F_x. Assume the exhaust flow is essentially horizontal.



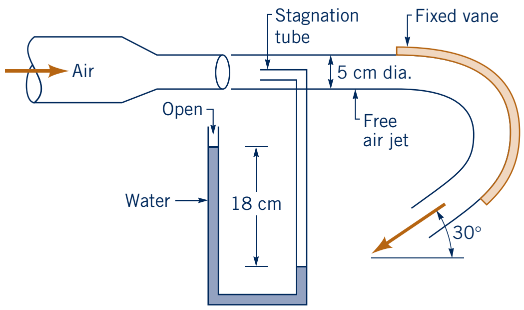
■ **Figure P5.64**

5.65 A horizontal circular jet of air strikes a stationary flat plate as indicated in Fig. P5.65. The jet velocity is 40 m/s and the jet diameter is 30 mm. If the air velocity magnitude remains constant as the air flows over the plate surface in the directions shown, determine: **(a)** the magnitude of F_A, the anchoring force required to hold the plate stationary; **(b)** the fraction of mass flow along the plate surface in each of the two directions shown; **(c)** the magnitude of F_A, the anchoring force required to allow the plate to move to the right at a constant speed of 10 m/s.



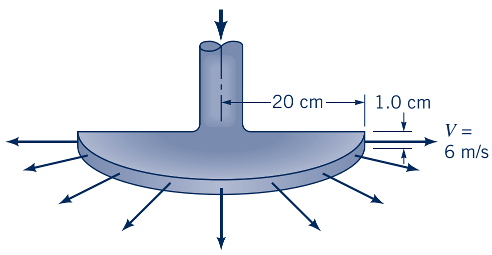
■ **Figure P5.65**

5.66 Air discharges from a 5 cm diameter nozzle and strikes a curved vane, which is in a vertical plane as shown in Fig. P5.66. A stagnation tube connected to a water U-tube manometer is located in the free air jet. Determine the horizontal component of the force that the air jet exerts on the vane. Neglect the weight of the air and all friction.



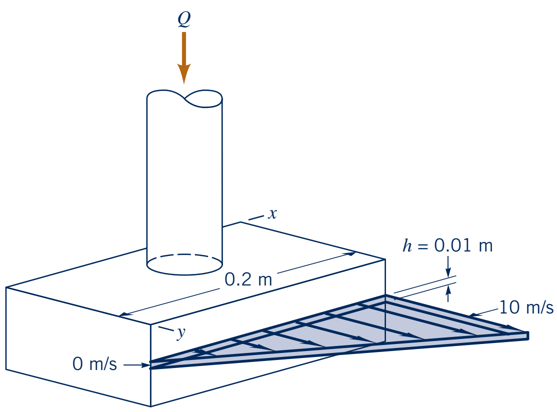
■ **Figure P5.66**

5.67 Water is sprayed radially outward over 180° as indicated in Fig. P5.67. The jet sheet is in the horizontal plane. If the jet velocity at the nozzle exit is 6 m/s, determine the direction and magnitude of the resultant horizontal anchoring force required to hold the nozzle in place.



■ **Figure P5.67**

5.68 A sheet of water of uniform thickness ($h = 0.01$ m) flows from the device shown in Fig. P5.68. The water enters vertically through the inlet pipe and exits horizontally with a speed that varies linearly from 0 to 10 m/s along the 0.2 m length of the slit. Determine the y component of anchoring force necessary to hold this device stationary.

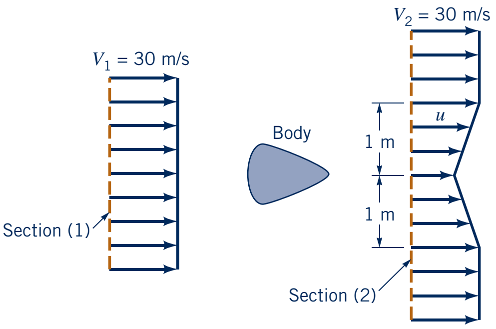


■ **Figure P5.68**

5.69 The results of a wind tunnel test to determine the drag on a body (see Fig. P5.69) are summarized below. The upstream [section (1)] velocity is uniform at 30 m/s. The static pressures are given by $p_1 = p_2 = 101$ kPa. The downstream velocity distribution, which is symmetrical about the centerline, is given by

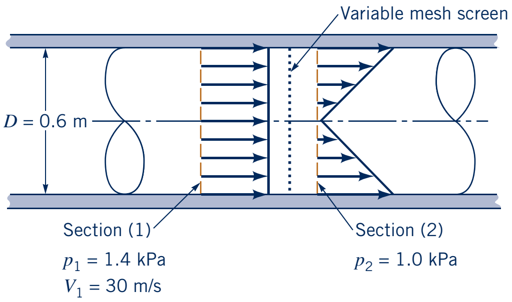
$$u = 30 - (9 - 3y)(1 - |y|) \qquad |y| \leq 1 \text{ m}$$
$$u = 30 \qquad |y| > 1 \text{ m}$$

where u is the velocity in m/s and y is the distance on either side of the centerline in feet (see Fig. P5.69). Assume that the body shape does not change in the direction normal to the paper. Calculate the drag force (reaction force in x direction) exerted on the air by the body per unit length normal to the plane of the sketch.



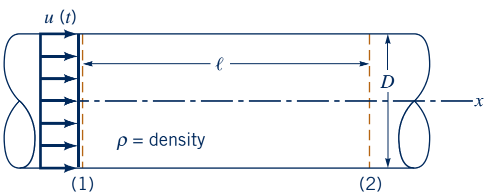
■ **Figure P5.69**

5.70 WILEY A variable mesh screen produces a linear and axisymmetric velocity profile as indicated in Fig. P5.70 in the airflow through a 0.6 m diameter circular cross-sectional duct. The static pressures upstream and downstream of the screen are 1.4 kPa and 1.0 kPa and are uniformly distributed over the flow cross-sectional area. Neglecting the force exerted by the duct wall on the flowing air, calculate the screen drag force.



■ **Figure P5.70**

5.71 Consider unsteady flow in the constant diameter, horizontal pipe shown in Fig. P5.71. The velocity is uniform throughout the entire pipe, but is a function of time: $\mathbf{V} = u(t)\,\hat{\mathbf{i}}$. Use the x component of the unsteady momentum equation to determine the pressure difference $p_1 - p_2$. Discuss how this result is related to $F_x = ma_x$.

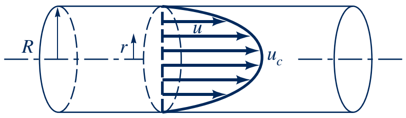


■ **Figure P5.71**

5.72 In a laminar pipe flow that is fully developed, the axial velocity profile is parabolic. That is,

$$u = u_c\left[1 - \left(\frac{r}{R}\right)^2\right]$$

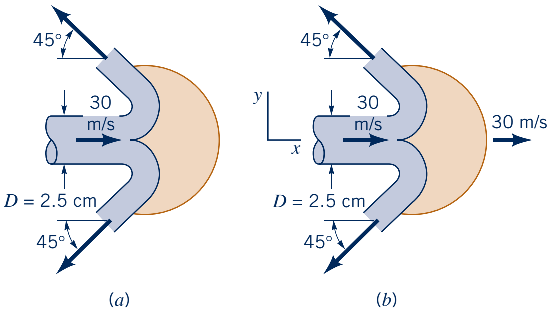
as is illustrated in Fig. P5.72. Compare the axial direction momentum flowrate calculated with the average velocity, $\bar{u}$, with the axial direction momentum flowrate calculated with the nonuniform velocity distribution taken into account.



■ **Figure P5.72**

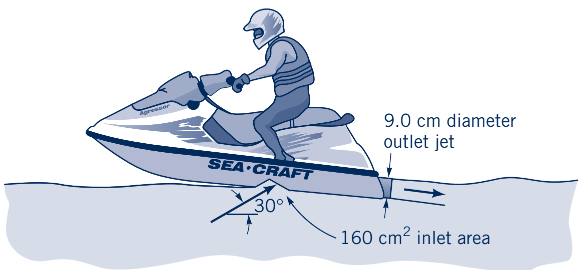
†5.73 Water from a garden hose is sprayed against your car to rinse dirt from it. Estimate the force that the water exerts on the car. List all assumptions and show calculations.

5.74 ▶ WILEY A Pelton wheel vane directs a horizontal, circular cross-sectional jet of water symmetrically as indicated in Fig. P5.74 and **Video V5.6**. The jet leaves the nozzle with a velocity of 30 m/s. Determine the x-direction component of anchoring force required to **(a)** hold the vane stationary, **(b)** confine the speed of the vane to a value of 30 m/s to the right. The fluid speed magnitude remains constant along the vane surface.



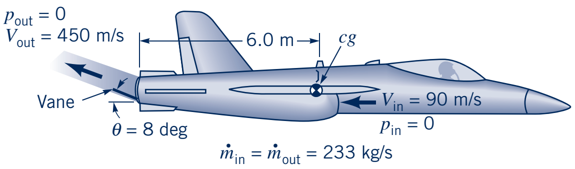
■ **Figure P5.74**

5.75 ▶ WILEY The thrust developed to propel the jet ski shown in **Video V9.18** and Fig. P5.75 is a result of water pumped through the vehicle and exiting as a high-speed water jet. For the conditions shown in the figure, what flowrate is needed to produce a 1.3 kN thrust? Assume the inlet and outlet jets of water are free jets.



■ **Figure P5.75**

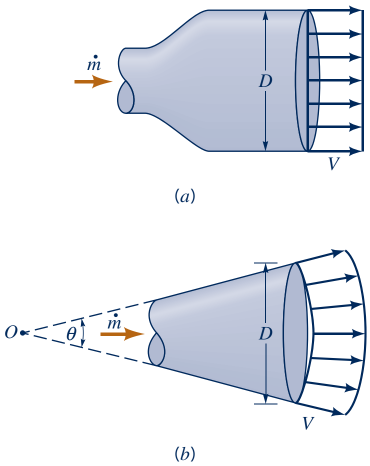
5.76 Thrust vector control is a technique that can be used to greatly improve the maneuverability of military fighter aircraft. It consists of using a set of vanes in the exit of a jet engine to deflect the exhaust gases as shown in Fig. P5.76. **(a)** Determine the pitching moment (the moment tending to rotate the nose of the aircraft



■ **Figure P5.76**

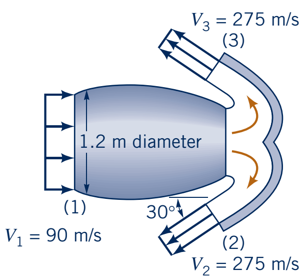
up) about the aircraft's mass center (cg) for the conditions indicated in the figure. **(b)** By how much is the thrust (force along the centerline of the aircraft) reduced for the case indicated compared to normal flight when the exhaust is parallel to the centerline?

5.77 The exhaust gas from the rocket shown in Fig. P5.77*a* leaves the nozzle with a uniform velocity parallel to the *x* axis. The gas is assumed to be discharged from the nozzle as a free jet. **(a)** Show that the thrust that is developed is equal to ρAV^2, where $A = \pi D^2/4$. **(b)** The exhaust gas from the rocket nozzle shown in Fig. P5.77*b* is also uniform, but rather than being directed along the *x* axis, it is directed along rays from point 0 as indicated. Determine the thrust for this rocket.



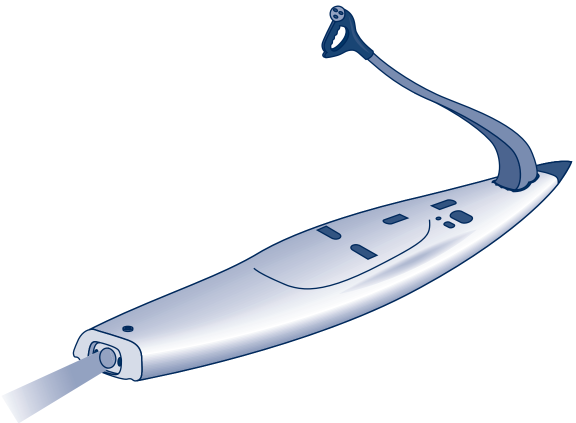
■ **Figure P5.77**

5.78 (See Fluids in the News article titled **"Where the Plume goes,"** Section 5.2.2.) Air flows into the jet engine shown in Fig. P5.78 at a rate of 131 kg/s and a speed of 90 m/s. Upon landing, the engine exhaust exits through the reverse thrust mechanism with a speed of 275 m/s in the direction indicated. Determine the reverse thrust applied by the engine to the airplane. Assume the inlet and exit pressures are atmospheric and that the mass flowrate of fuel is negligible compared to the air flowrate through the engine.



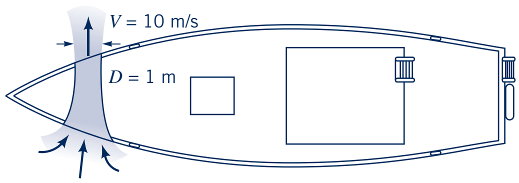
■ **Figure P5.78**

5.79 (See Fluids in the News article titled **"Motorized Surfboard,"** Section 5.2.2.) The thrust to propel the powered surfboard shown in Fig. P5.79 is a result of water pumped through the board that exits as a high-speed 7 cm diameter jet. Determine the flowrate and the velocity of the exiting jet if the thrust is to be 1.3 kN. Neglect the momentum of the water entering the pump.



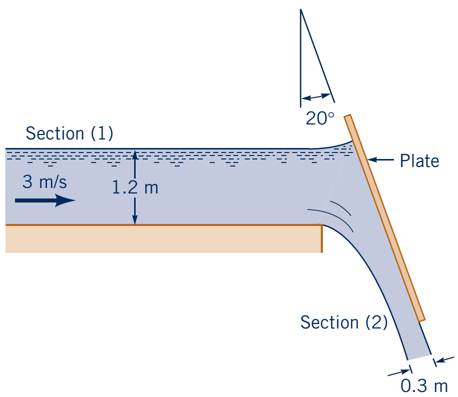
■ **Figure P5.79**

5.80 (See Fluids in the News article titled **"Bow Thrusters,"** Section 5.2.2.) The bow thruster on the boat shown in Fig. P5.80 is used to turn the boat. The thruster produces a 1 m diameter jet of water with a velocity of 10 m/s. Determine the force produced by the thruster. Assume that the inlet and outlet pressures are zero and that the momentum of the water entering the thruster is negligible.



■ **Figure P5.80**

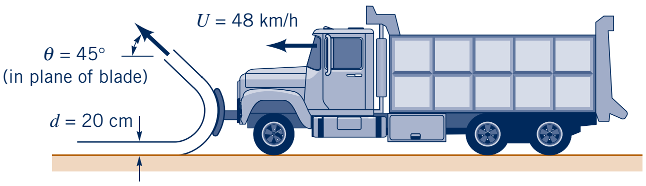
5.81 Water flows from a two-dimensional open channel and is diverted by an inclined plate as illustrated in Fig. P5.81. When the velocity at section (1) is 3 m/s, what horizontal force (per unit width) is required to hold the plate in position? At section (1) the pressure distribution is hydrostatic, and the fluid acts as a free jet at section (2). Neglect friction.



■ **Figure P5.81**

†5.82 If a valve in a pipe is suddenly closed, a large pressure surge may develop. For example, when the electrically operated shutoff valve in a dishwasher closes quickly, the pipes supplying the dishwasher may rattle or "bang" because of this large pressure pulse. Explain the physical mechanism for this "water hammer" phenomenon. How could this phenomenon be analyzed?

5.83 A snowplow mounted on a truck clears a path 3.6 m through heavy wet snow, as shown in Figure P5.83. The snow is 20 cm deep and its density is 160 kg/m^3. The truck travels at 48 km/h. The snow is discharged from the plow at an angle of 45° from the direction of travel and 45° above the horizontal, as shown in Figure P5.83. Estimate the force required to push the plow.



■ **Figure P5.83**

Section 5.2.3 Derivation of the Moment-of-Momentum Equation

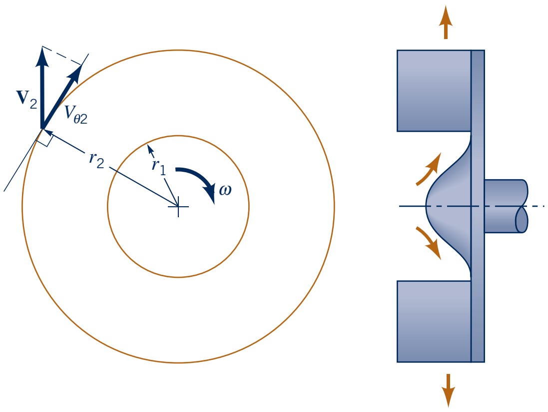
5.84 Describe a few examples (include photographs/images) of turbines where the force/torque of a flowing fluid leads to rotation of a shaft.

5.85 Describe a few examples (include photographs/images) of pumps where a fluid is forced to move by "blades" mounted on a rotating shaft.

5.86 An incompressible fluid flows outward through a blower as indicated in Fig. P5.86. The shaft torque involved, T_{shaft}, is estimated with the following relationship:

$$T_{\text{shaft}} = \dot{m} r_2 V_{\theta 2}$$

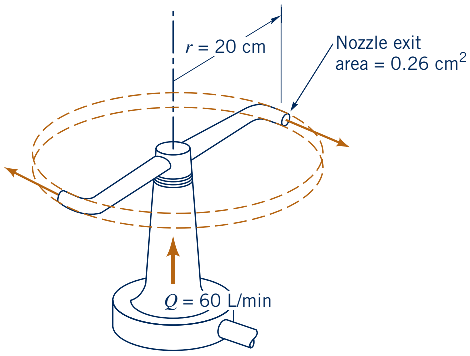
where $\dot{m}$ = mass flowrate through the blower, r_2 = outer radius of blower, and $V_{\theta 2}$ = tangential component of absolute fluid velocity leaving the blower. State the flow conditions that make this formula valid.



■ **Figure P5.86**

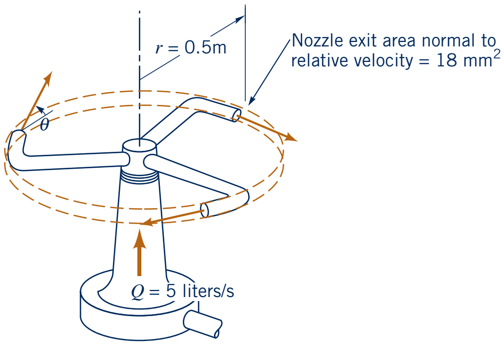
Section 5.2.4 Application of the Moment-of-Momentum Equation

5.87 Water enters a rotating lawn sprinkler through its base at the steady rate of 60 L/min as shown in Fig. P5.87. The exit cross-sectional area of each of the two nozzles is 0.26 cm^2, and the flow leaving each nozzle is tangential. The radius from the axis of rotation to the centerline of each nozzle is 20 cm. **(a)** Determine the resisting torque required to hold the sprinkler head stationary. **(b)** Determine the resisting torque associated with the sprinkler rotating with a constant speed of 500 rev/min. **(c)** Determine the angular velocity of the sprinkler if no resisting torque is applied.



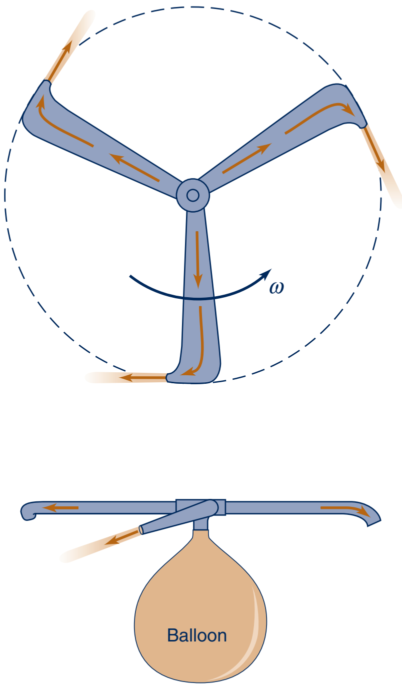
■ **Figure P5.87**

5.88 Five liters/s of water enter the rotor shown in **Video V5.10** and Fig. P5.88 along the axis of rotation. The cross-sectional area of each of the three nozzle exits normal to the relative velocity is 18 mm^2. How large is the resisting torque required to hold the rotor stationary? How fast will the rotor spin steadily if the resisting torque is reduced to zero and **(a)** $\theta = 0°$, **(b)** $\theta = 30°$, **(c)** $\theta = 60°$?



■ **Figure P5.88**

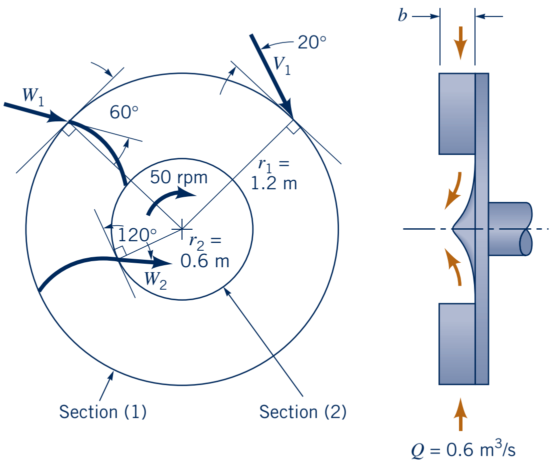
5.89 (See Fluids in the News article titled **"Tailless Helicopters,"** Section 5.2.4.) Shown in Fig. P5.89 is a toy "helicopter" powered



■ **Figure P5.89**

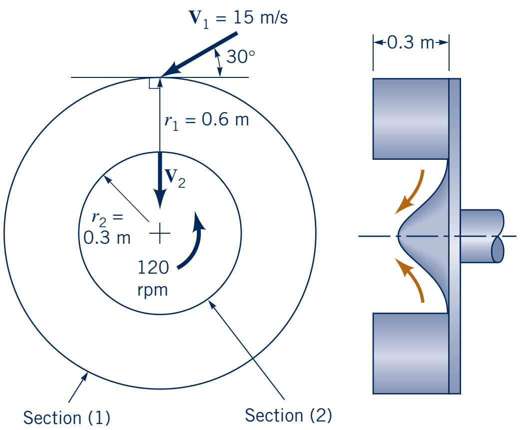
by air escaping from a balloon. The air from the balloon flows radially through each of the three propeller blades and out through small nozzles at the tips of the blades. Explain physically how this flow can cause the rotation necessary to rotate the blades to produce the needed lifting force.

5.90 A water turbine wheel rotates at the rate of 50 rpm in the direction shown in Fig. P5.90. The inner radius, r_2, of the blade row is 0.6 m, and the outer radius, r_1, is 1.2 m. The absolute velocity vector at the turbine rotor entrance makes an angle of 20° with the tangential direction. The inlet blade angle is 60° relative to the tangential direction. The blade outlet angle is 120°. The flowrate is 0.6 m^3/s. For the flow tangent to the rotor blade surface at inlet and outlet, determine an appropriate constant blade height, b, and the corresponding power available at the rotor shaft.



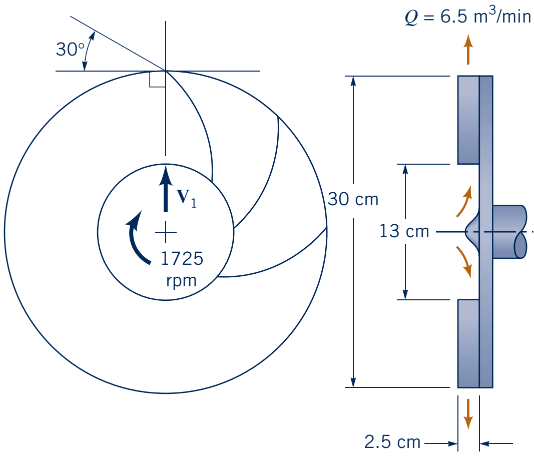
■ **Figure P5.90**

5.91 WILEY A water turbine with radial flow has the dimensions shown in Fig. P5.91. The absolute entering velocity is 15 m/s, and it makes an angle of 30° with the tangent to the rotor. The absolute exit velocity is directed radially inward. The angular speed of the rotor is 120 rpm. Find the power delivered to the shaft of the turbine.



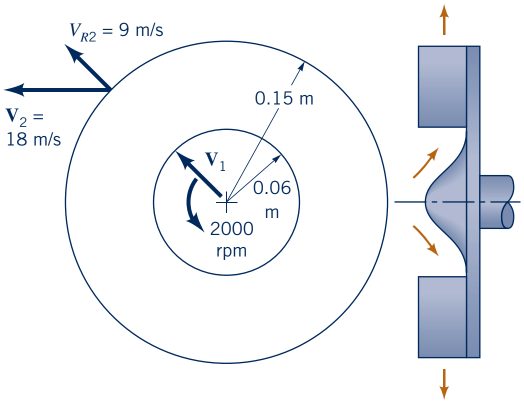
■ **Figure P5.91**

5.92 A fan (see Fig. P5.92) has a bladed rotor of 30 cm outside diameter and 13 cm inside diameter and runs at 1725 rpm. The width of each rotor blade is 2.5 cm from blade inlet to outlet. The volume flowrate is steady at 6.51 m^3/min, and the absolute velocity of the air at blade inlet, V_1, is purely radial. The blade discharge angle is 30° measured with respect to the tangential direction at the outside diameter of the rotor. **(a)** What would be a reasonable blade inlet angle (measured with respect to the tangential direction at the inside diameter of the rotor)? **(b)** Find the power required to run the fan.



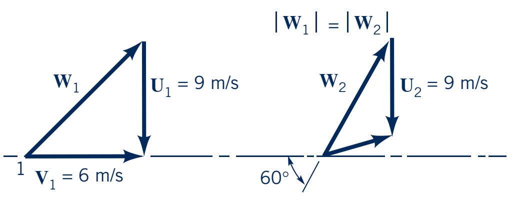
■ **Figure P5.92**

5.93 The radial component of velocity of water leaving the centrifugal pump sketched in Fig. P5.93 is 9 m/s. The magnitude of the absolute velocity at the pump exit is 18 m/s. The fluid enters the pump rotor radially. Calculate the shaft work required per unit mass flowing through the pump.



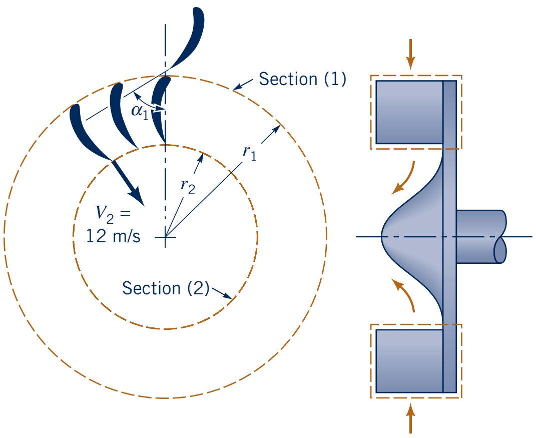
■ **Figure P5.93**

5.94 An axial flow turbomachine rotor involves the upstream (1) and downstream (2) velocity triangles shown in Fig. P5.94. Is this turbomachine a turbine or a fan? Sketch an appropriate blade section and determine energy transferred per unit mass of fluid.



■ **Figure P5.94**

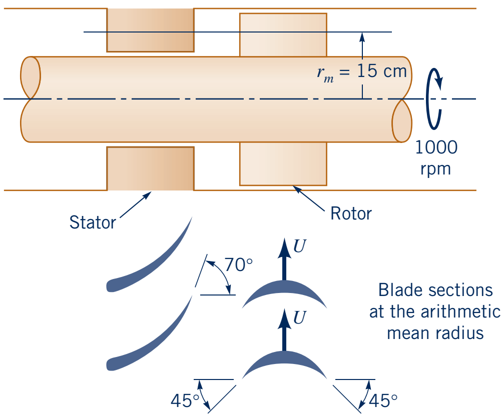
5.95 An inward flow radial turbine (see Fig. P5.95) involves a nozzle angle, α_1, of 60° and an inlet rotor tip speed, U_1, of 6 m/s. The ratio of rotor inlet to outlet diameters is 1.8. The absolute velocity leaving the rotor at section (2) is radial with a magnitude of



■ **Figure P5.95**

12 m/s. Determine the energy transfer per unit mass of fluid flowing through this turbine if the fluid is **(a)** air, **(b)** water.

5.96 A sketch of the arithmetic mean radius blade sections of an axial-flow water turbine stage is shown in Fig. P5.96. The rotor speed is 1000 rpm. **(a)** Sketch and label velocity triangles for the flow entering and leaving the rotor row. Use **V** for absolute velocity, **W** for relative velocity, and **U** for blade velocity. Assume flow enters and leaves each blade row at the blade angles shown. **(b)** Calculate the work per unit mass delivered at the shaft.



■ **Figure P5.96**

5.97 WILEY By using velocity triangles for flow upstream (1) and downstream (2) of a turbomachine rotor, prove that the shaft work in per unit mass flowing through the rotor is

$$w_{\text{shaft net in}} = \frac{V_2^2 - V_1^2 + U_2^2 - U_1^2 + W_1^2 - W_2^2}{2}$$

where V = absolute flow velocity magnitude, W = relative flow velocity magnitude, and U = blade speed.

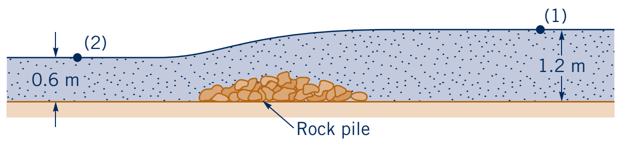
Section 5.3.1 Derivation of the Energy Equation

5.98 Distinguish between shaft work and other kinds of work associated with a flowing fluid.

5.99 WILEY An incompressible fluid flows along a 0.20 m diameter pipe with a uniform velocity of 3 m/s. If the pressure drop between the upstream and downstream sections of the pipe is 20 kPa, determine the power transferred to the fluid due to fluid normal stresses.

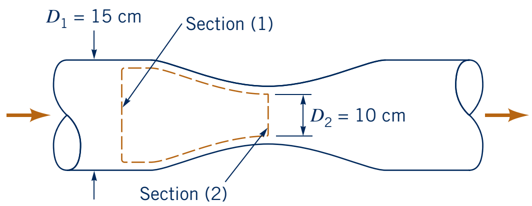
Section 5.3.2 Application of the Energy Equation—No Shaft Work and Section 5.3.3 Comparison of the Energy Equation with the Bernoulli Equation

5.100 A 30 m wide river with a flowrate of 70 m^3/s flows over a rock pile as shown in Fig. P5.100. Determine the direction of flow and the head loss associated with the flow across the rock pile.



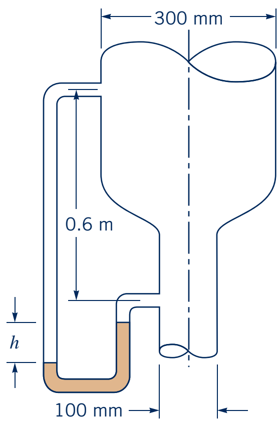
■ **Figure P5.100**

5.101 WILEY A horizontal Venturi flow meter consists of a converging–diverging conduit as indicated in Fig. P5.101. The diameters of cross sections (1) and (2) are 15 and 10 cm. The velocity and static pressure are uniformly distributed at cross sections (1) and (2). Determine the volume flowrate (m^3/s) through the meter if $p_1 - p_2$ = 21 kPa, the flowing fluid is oil (ρ = 890 kg/m^3), and the loss per unit mass from (1) to (2) is negligibly small.



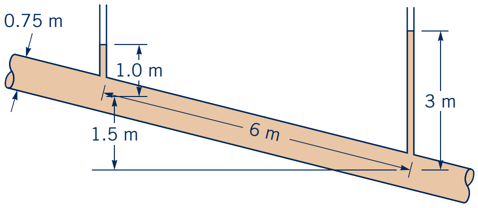
■ **Figure P5.101**

5.102 WILEY Oil (SG = 0.9) flows downward through a vertical pipe contraction as shown in Fig. P5.102. If the mercury manometer reading, h, is 100 mm, determine the volume flowrate for frictionless flow. Is the actual flowrate more or less than the frictionless value? Explain.



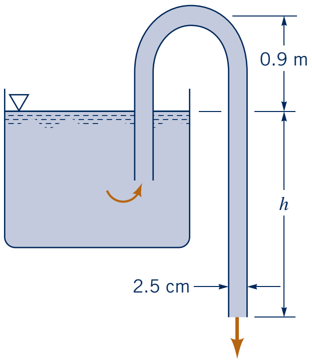
■ **Figure P5.102**

5.103 An incompressible liquid flows steadily along the pipe shown in Fig. P5.103. Determine the direction of flow and the head loss over the 6 m length of pipe.



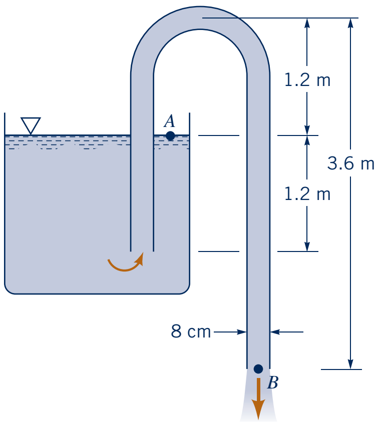
■ **Figure P5.103**

5.104 A siphon is used to draw water at 70 °F from a large container as indicated in Fig. P5.104. The inside diameter of the siphon line is 2.5 cm and the pipe centerline rises 0.9 m above the essentially constant water level in the tank. Show that by varying the length of the siphon below the water level, *h*, the rate of flow through the siphon can be changed. Assuming frictionless flow, determine the maximum flowrate possible through the siphon. The limiting condition is the occurrence of cavitation in the siphon. Will the actual maximum flow be more or less than the frictionless value? Explain.



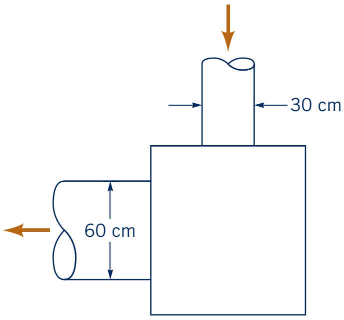
■ **Figure P5.104**

5.105 WILEY A water siphon having a constant inside diameter of 8 cm is arranged as shown in Fig. P5.105. If the friction loss between *A* and *B* is $0.8V^2/2$, where *V* is the velocity of flow in the siphon, determine the flowrate involved.



■ **Figure P5.105**

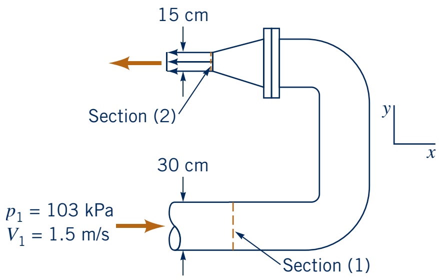
5.106 Water flows through a valve (see Fig. P5.106) at the rate of 450 kg/s. The pressure just upstream of the valve is 620 kPa and the pressure drop across the valve is 345 kPa. The inside diameters of the valve inlet and exit pipes are 30 and 60 cm. If the flow through the valve occurs in a horizontal plane, determine the loss in available energy across the valve.



■ **Figure P5.106**

5.107 A gas expands through a nozzle from a pressure of 2068 kPa to a pressure of 34 kPa. The enthalpy change involved, $\check{h}_1 - \check{h}_2$, is 350 kJ/kg. If the expansion is adiabatic but with frictional effects and the inlet gas speed is negligibly small, determine the exit gas velocity.

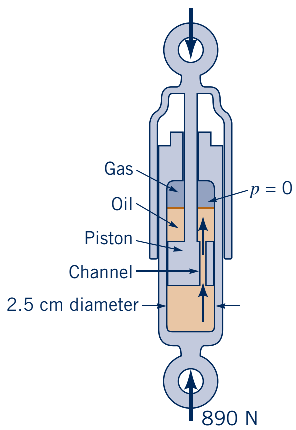
5.108 WILEY For the 180° elbow and nozzle flow shown in Fig. P5.108, determine the loss in available energy from section (1) to section (2). How much additional available energy is lost from section (2) to where the water comes to rest?



■ **Figure P5.108**

5.109 An automobile engine will work best when the back pressure at the interface of the exhaust manifold and the engine block is minimized. Show how reduction of losses in the exhaust manifold, piping, and muffler will also reduce the back pressure. How could losses in the exhaust system be reduced? What primarily limits the minimization of exhaust system losses?

5.110 WILEY (See Fluids in the News article titled **"Smart Shocks,"** Section 5.3.3.) A 890 N force applied to the end of the piston of the shock absorber shown in Fig. P5.110 causes the two ends of the shock absorber to move toward each other with a speed of 1.5 m/s. Determine the head loss associated with the flow of the oil through the channel. Neglect gravity and any friction force between the piston and cylinder walls.

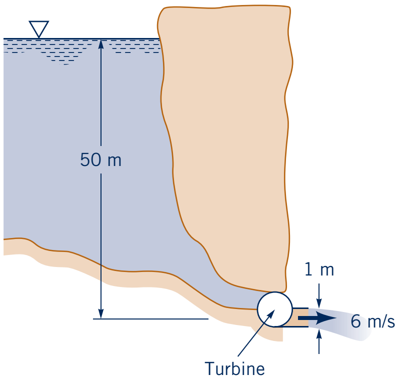


■ **Figure P5.110**

Section 5.3.2 Application of the Energy Equation—With Shaft Work

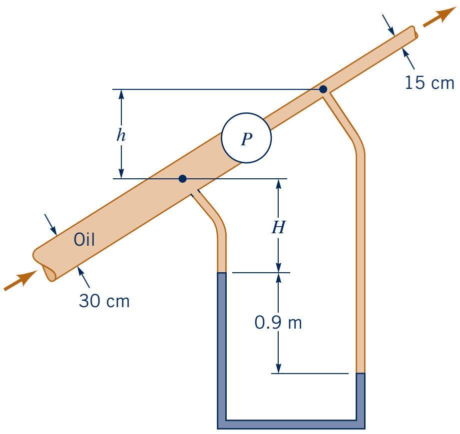
†**5.111** Based on flowrate and pressure rise information, estimate the power output of a human heart.

5.112 WILEY What is the maximum possible power output of the hydroelectric turbine shown in Fig. P5.112?



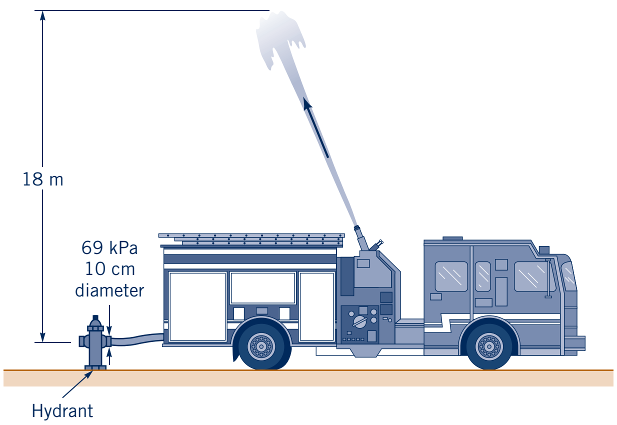
■ **Figure P5.112**

5.113 WILEY GO Oil ($SG = 0.88$) flows in an inclined pipe at a rate of 0.14 m^3/s as shown in Fig. P5.113. If the differential reading in the mercury manometer is 0.9 m, calculate the power that the pump supplies to the oil if head losses are negligible.



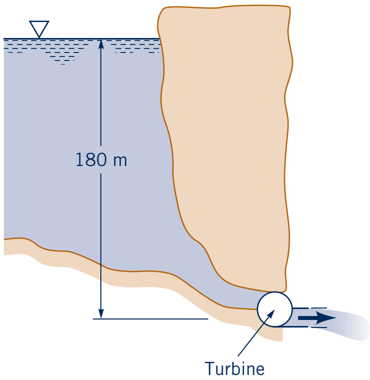
■ **Figure P5.113**

5.114 WILEY The pumper truck shown in Fig. P5.114 is to deliver 0.042 m^3/s to a maximum elevation of 18 m above the hydrant. The pressure at the 10 cm diameter outlet of the hydrant is 69 kPa. If head losses are negligibly small, determine the power that the pump must add to the water.



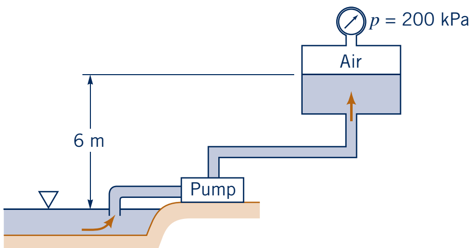
■ **Figure P5.114**

5.115 WILEY The hydroelectric turbine shown in Fig. P5.115 passes 500 kL/s across a head of 180 m. What is the maximum amount of power output possible? Why will the actual amount be less?



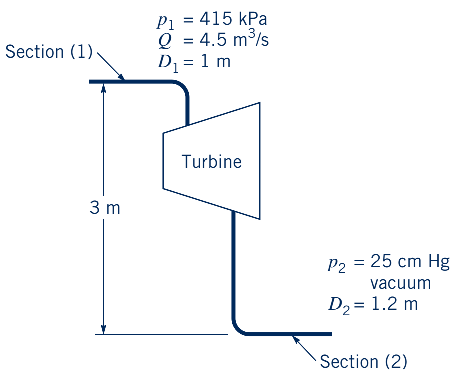
■ **Figure P5.115**

5.116 WILEY A pump is to move water from a lake into a large, pressurized tank as shown in Fig. P5.116 at a rate of 4000 liters in 10 min or less. Will a pump that adds 2.2 kW to the water work for this purpose? Support your answer with appropriate calculations. Repeat the problem if the tank were pressurized to 300, rather than 200, kPa.



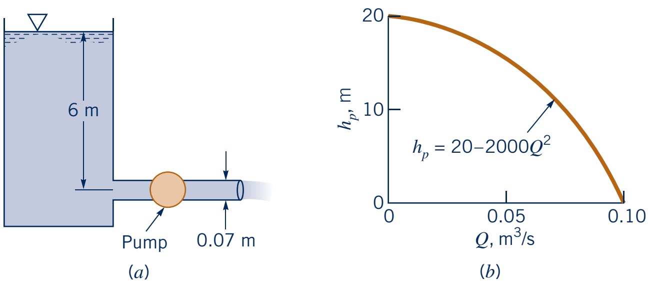
■ **Figure P5.116**

5.117 WILEY Water is supplied at 4.5 m^3/s and 415 kPa to a hydraulic turbine through a 1 m inside-diameter inlet pipe as indicated in Fig. P5.117. The turbine discharge pipe has a 1.2 m inside diameter. The static pressure at section (2), 3 m below the turbine inlet, is 25 cm Hg vacuum. If the turbine develops 1.9 MW, determine the power lost between sections (1) and (2).



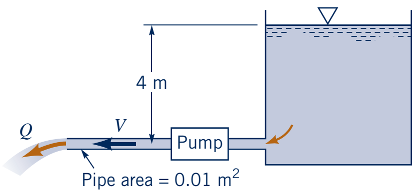
■ **Figure P5.117**

5.118 Water is pumped from the tank shown in Fig. P5.118*a*. The head loss is known to be $1.2\ V^2/2g$, where V is the average velocity in the pipe. According to the pump manufacturer, the relationship between the pump head and the flowrate is as shown in Fig. P5.118*b*: $h_p = 20 - 2000\ Q^2$, where h_p is in meters and Q is in m^3/s. Determine the flowrate, Q.



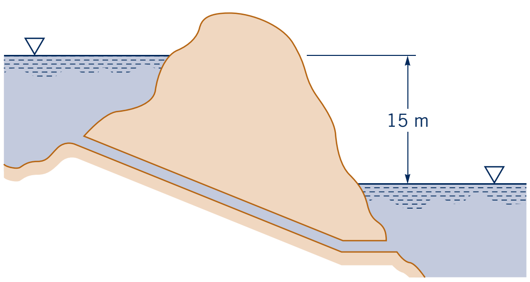
■ **Figure P5.118**

5.119 Water is pumped from the large tank shown in Fig. P5.119. The head loss is known to be equal to $4V^2/2g$ and the pump head is $h_p = 20 - 4Q^2$, where h_p is in m when Q is in m^3/s. Determine the flowrate.



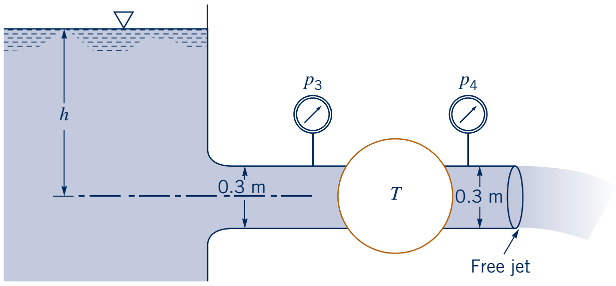
■ **Figure P5.119**

5.120 Water flows by gravity from one lake to another as sketched in Fig. P5.120 at the steady rate of 300 L/min. What is the loss in available energy associated with this flow? If this same amount of loss is associated with pumping the fluid from the lower lake to the higher one at the same flowrate, estimate the amount of pumping power required.



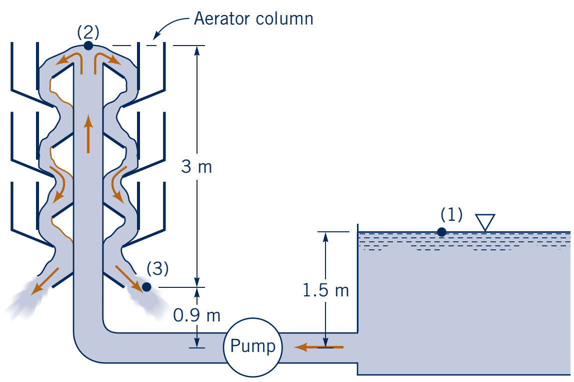
■ **Figure P5.120**

5.121 The turbine shown in Fig. P5.121 develops 73.5 W when the flowrate of water is 0.6 m^3/s. If all losses are negligible, determine **(a)** the elevation h, **(b)** the pressure difference across the turbine, and **(c)** the flowrate expected if the turbine were removed.



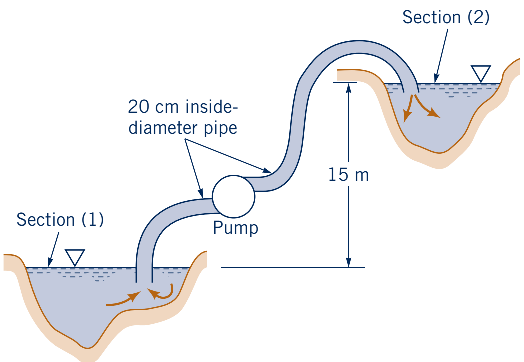
■ **Figure P5.121**

5.122 Water is pumped from a tank, point (1), to the top of a water plant aerator, point (2), as shown in **Video V5.16** and Fig. P5.122 at a rate of 0.085 m^3/s. **(a)** Determine the power that the pump adds to the water if the head loss from (1) to (2) where $V_2 = 0$ is 1.2 m. **(b)** Determine the head loss from (2) to the bottom of the aerator column, point (3), if the average velocity at (3) is $V_3 = 0.6$ m/s.



■ **Figure P5.122**

5.123 Water is to be moved from one large reservoir to another at a higher elevation as indicated in Fig. P5.123. The loss of available energy associated with 0.07 m^3/s being pumped from sections (1) to (2) is loss $= 61\overline{V}^2/0.2\ m^2/s^2$, where $\overline{V}$ is the average velocity of water in the 20 cm inside-diameter piping involved. Determine the amount of shaft power required.

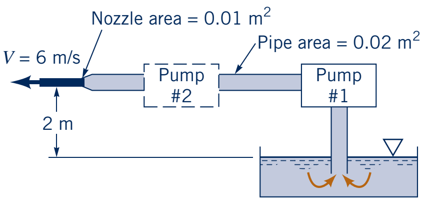


■ **Figure P5.123**

5.124 A 0.55 kW motor is required by an air-ventilating fan to produce a 60 cm diameter stream of air having a uniform speed of 12 m/s. Determine the aerodynamic efficiency of the fan.

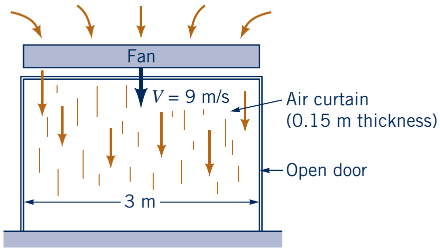
5.125 A pump moves water horizontally at a rate of 0.02 m^3/s. Upstream of the pump where the pipe diameter is 90 mm, the pressure is 120 kPa. Downstream of the pump where the pipe diameter is 30 mm, the pressure is 400 kPa. If the loss in energy across the pump due to fluid friction effects is 170 N · m/kg, determine the hydraulic efficiency of the pump.

5.126 WILEY Water is to be pumped from the large tank shown in Fig. P5.126 with an exit velocity of 6 m/s. It was determined that the original pump (pump 1) that supplies 1 kW of power to the water did not produce the desired velocity. Hence, it is proposed that an additional pump (pump 2) be installed as indicated to increase the flowrate to the desired value. How much power must pump 2 add to the water? The head loss for this flow is $h_L = 250\ Q^2$, where h_L is in m when Q is in m^3/s.



■ **Figure P5.126**

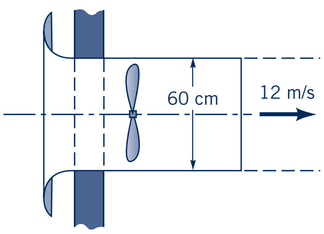
5.127 WILEY (See Fluids in the News article titled **"Curtain of Air,"** Section 5.3.3.) The fan shown in Fig. P5.127 produces an air curtain to separate a loading dock from a cold storage room. The air curtain is a jet of air 3 m wide, 0.15 m thick moving with speed $V = 9$ m/s. The loss associated with this flow is loss $= K_L V^2/2$, where $K_L = 5$. How much power must the fan supply to the air to produce this flow?



■ **Figure P5.127**

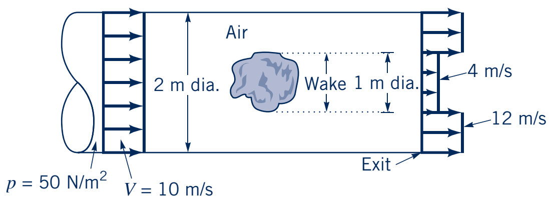
Section 5.3.3 Application of the Energy Equation—Combined with Linear Momentum

5.128 If a 0.5 W motor is required by a ventilating fan to produce a 60 cm stream of air having a velocity of 12 m/s as shown in Fig. P5.128, estimate **(a)** the efficiency of the fan and **(b)** the thrust of the supporting member on the conduit enclosing the fan.



■ **Figure P5.128**

5.129 WILEY Air flows past an object in a pipe of 2 m diameter and exits as a free jet as shown in Fig. P5.129. The velocity and pressure upstream are uniform at 10 m/s and 50 N/m^2, respectively. At the pipe exit the velocity is nonuniform as indicated. The shear stress along the pipe wall is negligible. **(a)** Determine the head loss associated with a particle as it flows from the uniform velocity upstream of the object to a location in the wake at the exit plane of the pipe. **(b)** Determine the force that the air exerts on the object.



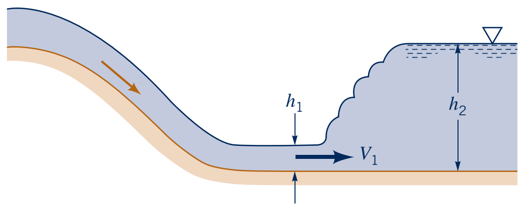
■ **Figure P5.129**

5.130 Near the downstream end of a river spillway, a hydraulic jump often forms, as illustrated in Fig. P5.130 and **Video V10.11.** The velocity of the channel flow is reduced abruptly across the jump. Using the conservation of mass and linear momentum principles, derive the following expression for h_2,

$$h_2 = -\frac{h_1}{2} + \sqrt{\left(\frac{h_1}{2}\right)^2 + \frac{2V_1^2 h_1}{g}}$$

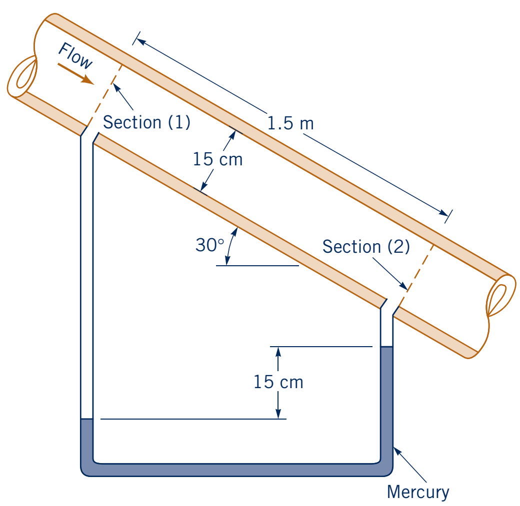
The loss of available energy across the jump can also be determined if energy conservation is considered. Derive the loss expression

$$\text{jump loss} = \frac{g(h_2 - h_1)^3}{4h_1h_2}$$



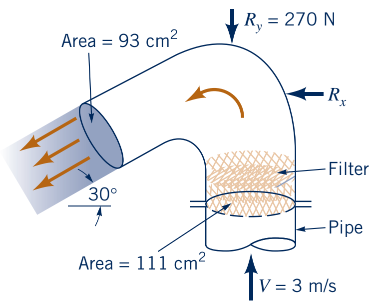
■ **Figure P5.130**

5.131 WILEY Water flows steadily down the inclined pipe as indicated in Fig P5.131. Determine the following: **(a)** the difference in pressure $p_1 - p_2$, **(b)** the loss between sections (1) and (2), **(c)** the net axial force exerted by the pipe wall on the flowing water between sections (1) and (2).



■ **Figure P5.131**

5.132 Water flows steadily in a pipe and exits as a free jet through an end cap that contains a filter as shown in Fig. P5.132. The flow is in a horizontal plane. The axial component, R_y, of the anchoring force needed to keep the end cap stationary is 270 N. Determine the head loss for the flow through the end cap.

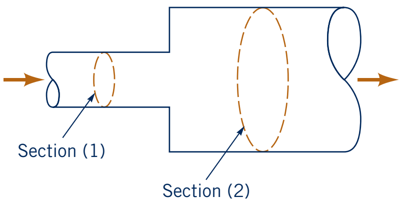


■ **Figure P5.132**

5.133 When fluid flows through an abrupt expansion as indicated in Fig. P5.133, the loss in available energy across the expansion, loss_{ex}, is often expressed as

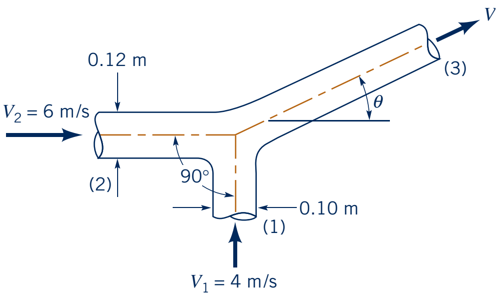
$$\text{loss}_{ex} = \left(1 - \frac{A_1}{A_2}\right)^2 \frac{V_1^2}{2}$$

where A_1 = cross-sectional area upstream of expansion, A_2 = cross-sectional area downstream of expansion, and V_1 = velocity of flow upstream of expansion. Derive this relationship.



■ **Figure P5.133**

5.134 Two water jets collide and form one homogeneous jet as shown in Fig. P5.134. **(a)** Determine the speed, V, and direction, θ, of the combined jet. **(b)** Determine the loss for a fluid particle flowing from (1) to (3), from (2) to (3). Gravity is negligible.



■ **Figure P5.134**

Section 5.3.4 Application of the Energy Equation to Nonuniform Flows

5.135 Water flows vertically upward in a circular cross-sectional pipe. At section (1), the velocity profile over the cross-sectional area is uniform. At section (2), the velocity profile is

$$\mathbf{V} = w_c\left(\frac{R - r}{R}\right)^{1/7} \hat{\mathbf{k}}$$

where $\mathbf{V}$ = local velocity vector, w_c = centerline velocity in the axial direction, R = pipe inside radius, and r = radius from pipe axis. Develop an expression for the loss in available energy between sections (1) and (2).

5.136 A small fan moves air at a mass flowrate of 0.002 kg/s. Upstream of the fan, the pipe diameter is 6.4 cm, the flow is laminar, the velocity distribution is parabolic, and the kinetic energy coefficient, α_1, is equal to 2.0. Downstream of the fan, the pipe diameter is 2.5 cm, the flow is turbulent, the velocity profile is quite flat, and the kinetic energy coefficient, α_2, is equal to 1.08. If the rise in static pressure across the fan is 103 Pa and the fan shaft draws 0.18 W, compare the value of loss calculated: **(a)** assuming uniform velocity distributions, **(b)** considering actual velocity distributions.

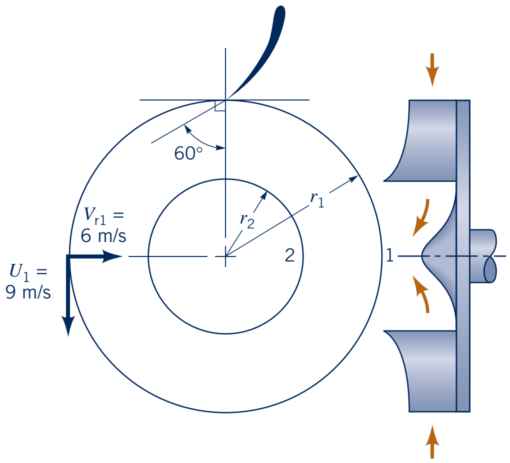
Section 5.3.5 Combination of the Energy Equation and the Moment-of-Momentum Equation

5.137 Air enters a radial blower with zero angular momentum. It leaves with an absolute tangential velocity, V_θ, of 60 m/s. The rotor blade speed at rotor exit is 50 m/s. If the stagnation pressure rise across the rotor is 3 kPa, calculate the loss of available energy across the rotor and the rotor efficiency.

5.138 Water enters a pump impeller radially. It leaves the impeller with a tangential component of absolute velocity of 10 m/s. The impeller exit diameter is 60 mm, and the impeller speed is 1800 rpm. If the stagnation pressure rise across the impeller is 45 kPa, determine the loss of available energy across the impeller and the hydraulic efficiency of the pump.

5.139 Water enters an axial-flow turbine rotor with an absolute velocity tangential component, V_θ, of 4.5 m. The corresponding blade velocity, U, is 15 m. The water leaves the rotor blade row with no angular momentum. If the stagnation pressure drop across the turbine is 83 kPa, determine the hydraulic efficiency of the turbine.

5.140 An inward flow radial turbine (see Fig. P5.140) involves a nozzle angle, α_1, of 60° and an inlet rotor tip speed, U_1, of 9 m/s. The ratio of rotor inlet to outlet diameters is 2.0. The radial component of velocity remains constant at 6 m/s through the rotor, and the flow leaving the rotor at section (2) is without angular momentum. If the flowing fluid is water and the stagnation pressure drop across the rotor is 110 kPa, determine the loss of available energy across the rotor and the hydraulic efficiency involved.



■ **Figure P5.140**

Section 5.3.4 Application of the Energy Equation to Nonuniform Flows

5.141 The distribution of axial direction velocity, u, in a pipe flow is linear from zero at the wall to maximum of u_c at the centerline. Determine the average velocity, $\bar{u}$, and the kinetic energy coefficient, α.

Lab Problems

5.1LP This problem involves the force that a jet of air exerts on a flat plate as the air is deflected by the plate. To proceed with this problem, go to Appendix H, which is located in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.

5.2LP This problem involves the pressure distribution produced on a flat plate that deflects a jet of air. To proceed with this problem, go to Appendix H, which is located in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.

5.3LP This problem involves the force that a jet of water exerts on a vane when the vane turns the jet through a given angle. To proceed with this problem, go to Appendix H, which is located in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.

5.4LP This problem involves the force needed to hold a pipe elbow stationary. To proceed with this problem, go to Appendix H, which is located in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.

Lifelong Learning Problems

5.1LL What are typical efficiencies associated with swimming and how can they be improved?

5.2LL Explain how local ionization of flowing air can accelerate it. How can this be useful?

5.3LL Discuss the main causes of loss of available energy in a turbo-pump and how they can be minimized. What are typical turbo-pump efficiencies?

5.4LL Discuss the main causes of loss of available energy in a turbine and how they can be minimized. What are typical turbine efficiencies?

FE Exam Problems

Sample FE (Fundamentals of Engineering) exam questions for fluid mechanics are provided in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.