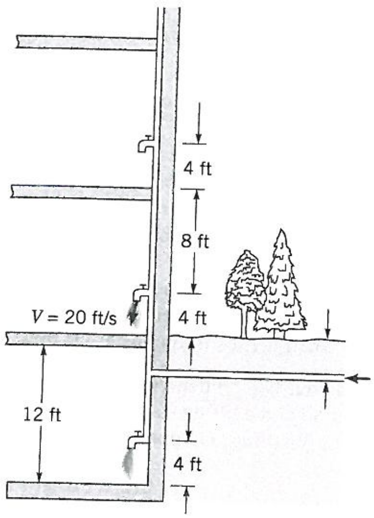
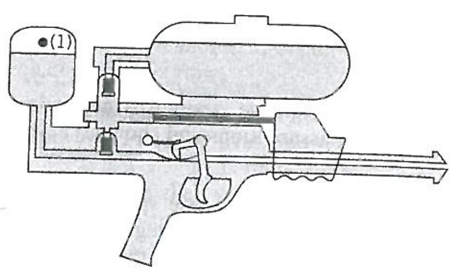
from the basement faucet and from the faucet on the second floor (assume each floor is 12 ft tall).



■ **Figure P3.31**

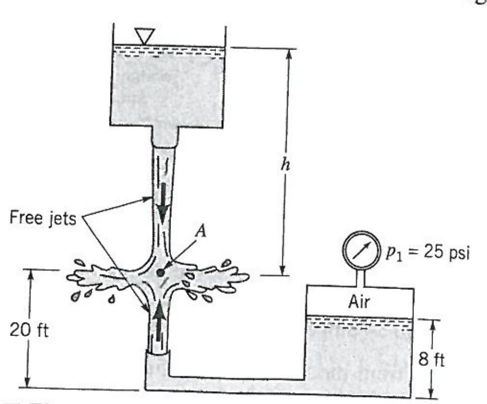
3.32 Laboratories containing dangerous materials are often kept at a pressure slightly less than ambient pressure so that contaminants can be filtered through an exhaust system rather than leaked through cracks around doors, etc. If the pressure in such a room is 0.1 in. of water below that of the surrounding rooms, with what velocity will air enter the room through an opening? Assume viscous effects are negligible.

†3.33 The "supersoaker" water gun shown in Fig. P3.33 can shoot more than 30 ft in the horizontal direction. Estimate the minimum pressure, p_1, needed in the chamber in order to accomplish this. List all assumptions and show all calculations.



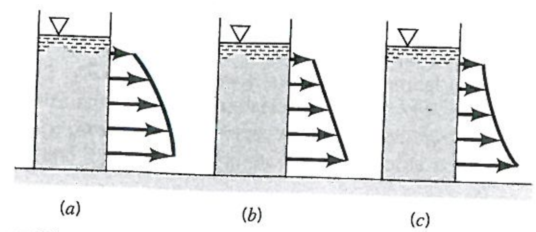
■ **Figure P3.33**

3.34 WILEY Streams of water from two tanks impinge upon each other as shown in Fig. P3.34. If viscous effects are negligible and point A is a stagnation point, determine the height h.



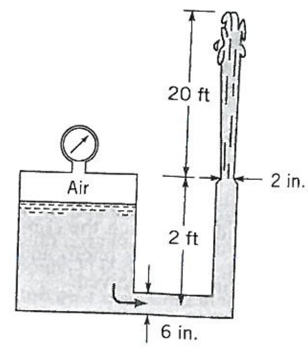
■ **Figure P3.34**

3.35 Several holes are punched into a tin can as shown in Fig. P3.35. Which of the figures represents the variation of the water velocity as it leaves the holes? Justify your choice.



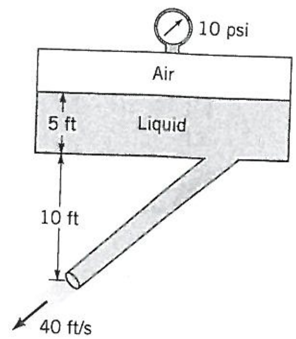
■ **Figure P3.35**

3.36 WILEY Water flows from a pressurized tank, through a 6-in.-diameter pipe, exits from a 2-in.-diameter nozzle, and rises 20 ft above the nozzle as shown in Fig. P3.36. Determine the pressure in the tank if the flow is steady, frictionless, and incompressible.



■ **Figure P3.36**

3.37 WILEY An inviscid, incompressible liquid flows steadily from the large pressurized tank shown in Fig. P.3.37. The velocity at the exit is 40 ft/s. Determine the specific gravity of the liquid in the tank.



■ **Figure P3.37**

Section 3.6.2 Confined Flows (also see Lab Problems 3.1LP and 3.3LP)

3.38 Obtain a photograph/image of a situation that involves a confined flow for which the Bernoulli and continuity equations are important. Print this photo and write a brief paragraph that describes the situation involved.

3.39 Air flows steadily through a horizontal 4-in.-diameter pipe and exits into the atmosphere through a 3-in.-diameter nozzle. The velocity at the nozzle exit is 150 ft/s. Determine the pressure in the pipe if viscous effects are negligible.

3.40 For the pipe enlargement shown in Fig. P3.40, the pressures at sections (1) and (2) are 56.3 and 58.2 psi, respectively. Determine the weight flowrate (lb/s) of the gasoline in the pipe.

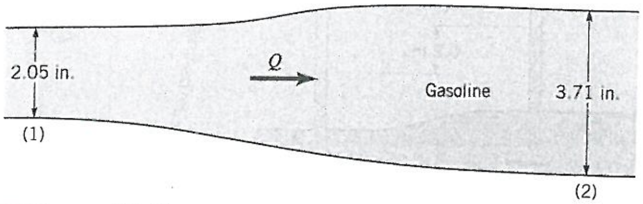


Figure P3.40

3.41 WILEY GO A fire hose nozzle has a diameter of $1\frac{1}{8}$ in. According to some fire codes, the nozzle must be capable of delivering at least 250 gal/min. If the nozzle is attached to a 3-in.-diameter hose, what pressure must be maintained just upstream of the nozzle to deliver this flowrate?

3.42 WILEY Water flowing from the 0.75-in.-diameter outlet shown in **Video V8.15** and Fig. P3.42 rises 2.8 in. above the outlet. Determine the flowrate.

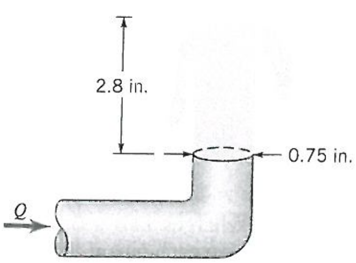


Figure P3.42

3.43 Pop (with the same properties as water) flows from a 4-in.-diameter pop container that contains three holes as shown in Fig. P3.43 (see **Video 3.9**). The diameter of each fluid stream is 0.15 in., and the distance between holes is 2 in. If viscous effects are negligible and quasi-steady conditions are assumed, determine the time at which the pop stops draining from the top hole. Assume the pop surface is 2 in. above the top hole when $t = 0$. Compare your results with the time you measure from the video.

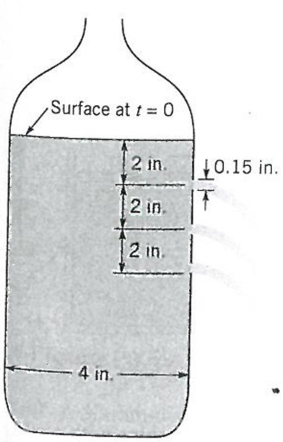


Figure P3.43

3.44 Water flows steadily through the large tanks shown in Fig. P3.44. Determine the water depth, h_A.

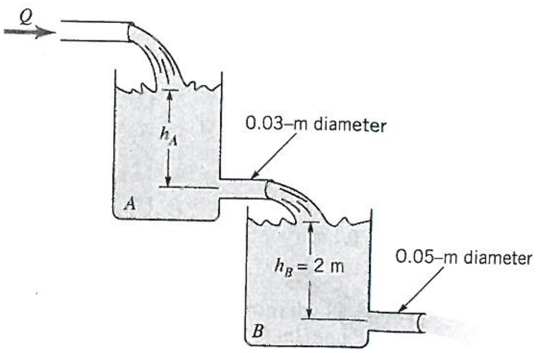


Figure P3.44

3.45 Water (assumed inviscid and incompressible) flows steadily in the vertical variable-area pipe shown in Fig. P3.45. Determine the flowrate if the pressure in each of the gages reads 50 kPa.

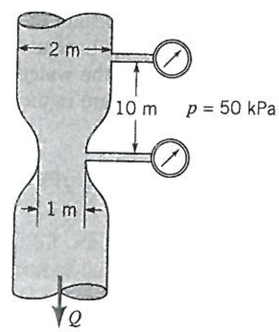


Figure P3.45

3.46 WILEY Air is drawn into a wind tunnel used for testing automobiles as shown in Fig. P3.46. **(a)** Determine the manometer reading, h, when the velocity in the test section is 60 mph. Note that there is a 1-in. column of oil on the water in the manometer. **(b)** Determine the difference between the stagnation pressure on the front of the automobile and the pressure in the test section.

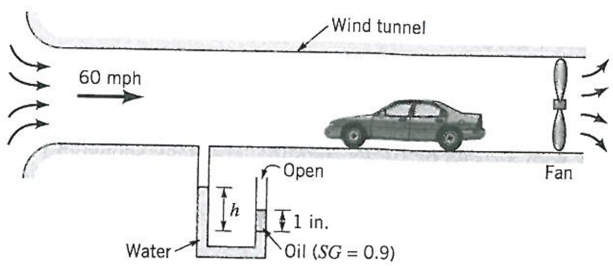
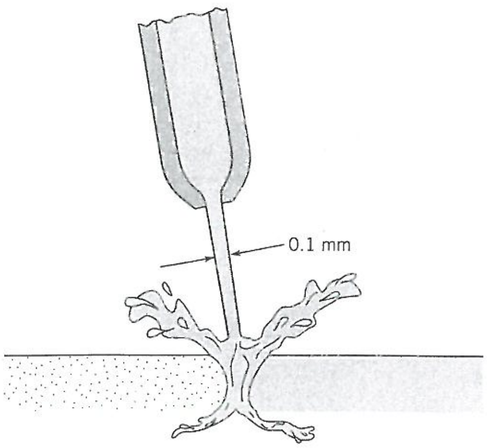


Figure P3.46

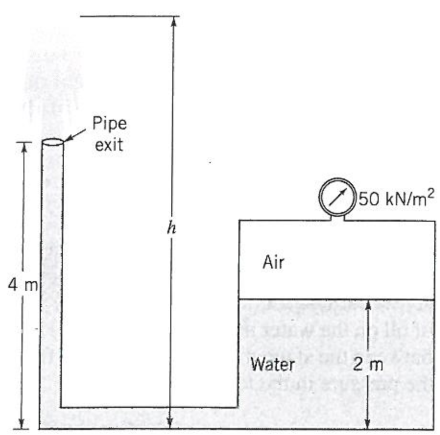
3.47 Natural gas (methane) flows from a 3-in.-diameter gas main, through a 1-in.-diameter pipe, and into the burner of a furnace at a rate of 100 ft^3/hour. Determine the pressure in the gas main if the pressure in the 1-in. pipe is to be 6 in. of water greater than atmospheric pressure. Neglect viscous effects.

3.48 WILEY Small-diameter, high-pressure liquid jets can be used to cut various materials as shown in Fig. P3.48. If viscous effects are negligible, estimate the pressure needed to produce a 0.10-mm-diameter water jet with a speed of 700 m/s. Determine the flowrate.



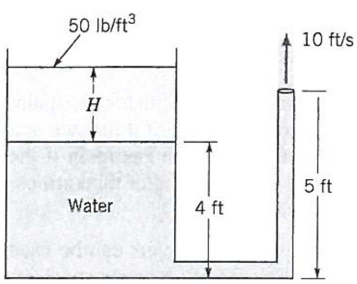
■ **Figure P3.48**

3.49 Water (assumed frictionless and incompressible) flows steadily from a large tank and exits through a vertical, constant diameter pipe as shown in Fig. P3.49. The air in the tank is pressurized to 50 kN/m^2. Determine **(a)** the height h, to which the water rises, **(b)** the water velocity in the pipe, and **(c)** the pressure in the horizontal part of the pipe.



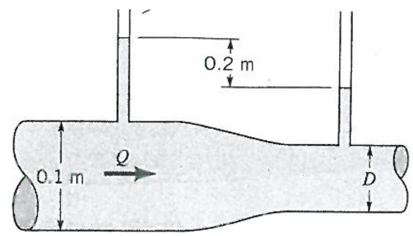
■ **Figure P3.49**

3.50 Water (assumed inviscid and incompressible) flows steadily with a speed of 10 ft/s from the large tank shown in Fig. P3.50. Determine the depth, H, of the layer of light liquid (specific weight = 50 lb/ft^3) that covers the water in the tank.



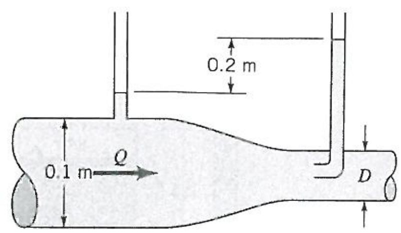
■ **Figure P3.50**

3.51 Water flows through the pipe contraction shown in Fig. P3.51. For the given 0.2-m difference in manometer level, determine the flowrate as a function of the diameter of the small pipe, D.



■ **Figure P3.51**

3.52 Water flows through the pipe contraction shown in Fig. P3.52. For the given 0.2-m difference in the manometer level, determine the flowrate as a function of the diameter of the small pipe, D.

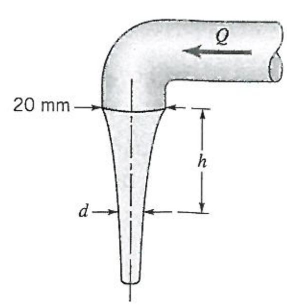


■ **Figure P3.52**

3.53 A 0.15-m-diameter pipe discharges into a 0.10-m-diameter pipe. Determine the velocity head in each pipe if they are carrying 0.12 m^3/s of kerosene.

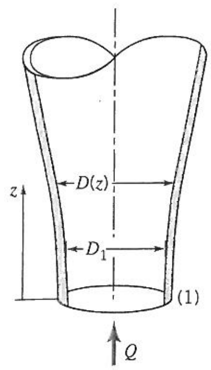
3.54 Carbon tetrachloride flows in a pipe of variable diameter with negligible viscous effects. At point A in the pipe the pressure and velocity are 20 psi and 30 ft/s, respectively. At location B the pressure and velocity are 23 psi and 14 ft/s. Which point is at the higher elevation and by how much?

*3.55 Water flows from a 20-mm-diameter pipe with a flowrate Q as shown in Fig. P3.55. Plot the diameter of the water stream, d, as a function of distance below the faucet, h, for values of $0 \le h \le 1$ m and $0 \le Q \le 0.004$ m^3/s. Discuss the validity of the one-dimensional assumption used to calculate $d = d(h)$, noting, in particular, the conditions of small h and small Q.



■ **Figure P3.55**

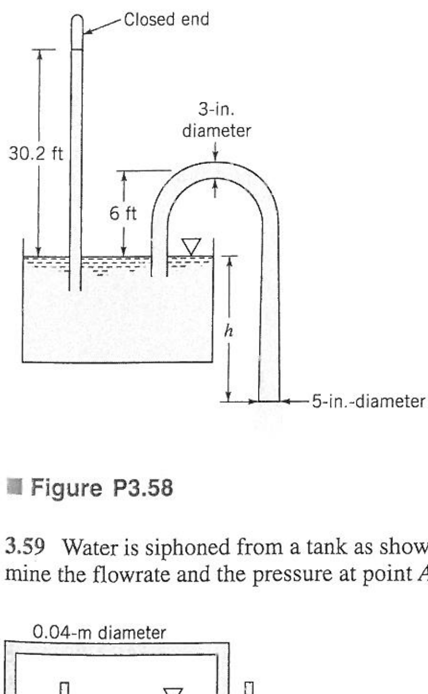
3.56 Water flows upward through a variable area pipe with a constant flowrate, Q, as shown in Fig. P3.56. If viscous effects are negligible, determine the diameter, $D(z)$, in terms of D_1 if the pressure is to remain constant throughout the pipe. That is, $p(z) = p_1$.



■ Figure P3.56

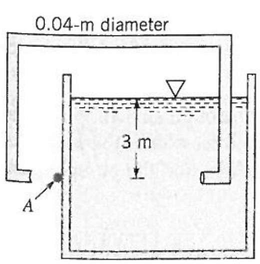
3.57 WILEY The circular stream of water from a faucet is observed to taper from a diameter of 20 mm to 10 mm in a distance of 50 cm. Determine the flowrate.

3.58 WILEY GO Water is siphoned from the tank shown in Fig. P3.58. The water barometer indicates a reading of 30.2 ft. Determine the maximum value of h allowed without cavitation occurring. Note that the pressure of the vapor in the closed end of the barometer equals the vapor pressure.



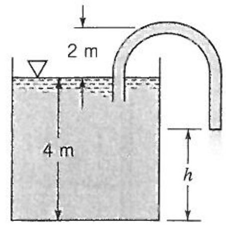
■ Figure P3.58

3.59 Water is siphoned from a tank as shown in Fig. P3.59. Determine the flowrate and the pressure at point A, a stagnation point.



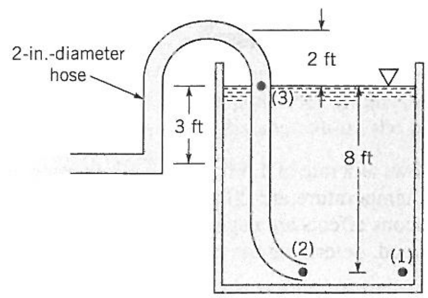
■ Figure P3.59

3.60 A 50-mm-diameter plastic tube is used to siphon water from the large tank shown in Fig. P3.60. If the pressure on the outside of the tube is more than 30 kPa greater than the pressure within the tube, the tube will collapse and siphon will stop. If viscous effects are negligible, determine the minimum value of h allowed without the siphon stopping.



■ Figure P3.60

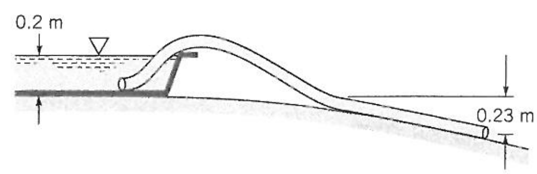
3.61 Water is siphoned from the tank shown in Fig. P3.61. Determine the flowrate from the tank and the pressure at points (1), (2), and (3) if viscous effects are negligible.



■ Figure P3.61

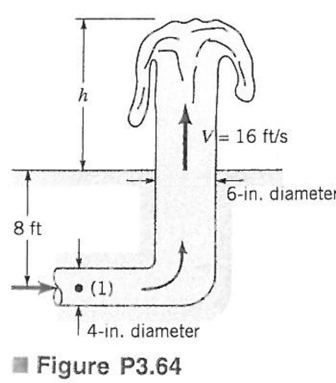
3.62 Redo Problem 3.61 if a 1-in-diameter nozzle is placed at the end of the tube.

3.63 WILEY A smooth plastic, 10-m-long garden hose with an inside diameter of 20 mm is used to drain a wading pool as is shown in Fig. P3.63. If viscous effects are neglected, what is the flowrate from the pool?

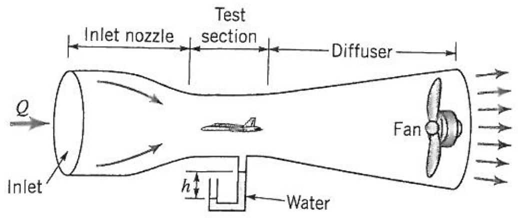


■ Figure P3.63

3.64 WILEY Water exits a pipe as a free jet and flows to a height h above the exit plane as shown in Fig. P3.64. The flow is steady, incompressible, and frictionless. **(a)** Determine the height h. **(b)** Determine the velocity and pressure at section (1).

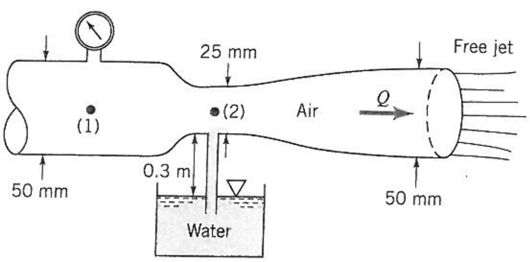


■ Figure P3.64



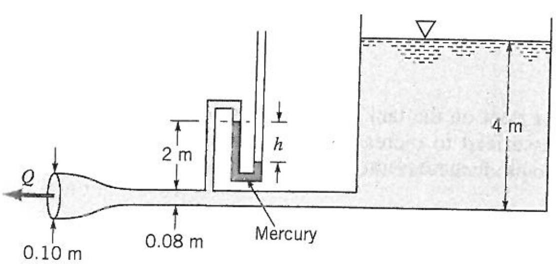
■ **Figure P3.74**

3.75 Air flows through the device shown in Fig. P3.75. If the flowrate is large enough, the pressure within the constriction will be low enough to draw the water up into the tube. Determine the flowrate, Q, and the pressure needed at section (1) to draw the water into section (2). Neglect compressibility and viscous effects.



■ **Figure P3.75**

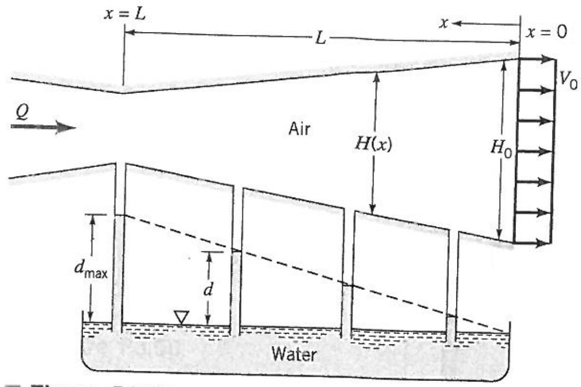
3.76 WILEY Water flows steadily from the large open tank shown in Fig. 3.76. If viscous effects are negligible, determine **(a)** the flowrate, Q, and **(b)** the manometer reading, h.



■ **Figure P3.76**

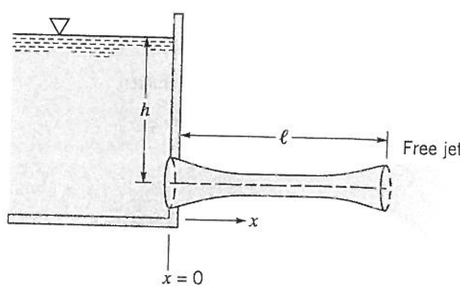
3.77 WILEY Water from a faucet fills a 16-oz glass (volume = 28.9 in.^{3}) in 20 s. If the diameter of the jet leaving the faucet is 0.60 in., what is the diameter of the jet when it strikes the water surface in the glass which is positioned 14 in. below the faucet?

3.78 Air flows steadily through a converging–diverging rectangular channel of constant width as shown in Fig. 3.78 and **Video V3.10**. The height of the channel at the exit and the exit velocity are H_0 and V_0 respectively. The channel is to be shaped so that the distance, d, that water is drawn up into tubes attached to static pressure taps along the channel wall is linear with distance along the channel. That is $d = (d_{max}/L)\, x$, where L is the channel length and d_{max} is the maximum water depth (at the minimum channel height: $x = L$). Determine the height, $H(x)$, as a function of x and the other important parameters.



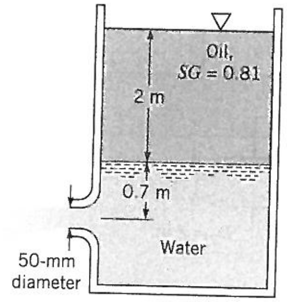
■ **Figure P3.78**

*3.79 Water flows from a large tank and through a pipe of variable area as shown in Fig. 3.79. The area of the pipe is given by $A = A_0[1 - x(1 - x/\ell)/2\ell]$, where A_0 is the area at the beginning ($x = 0$) and end ($x = \ell$) of the pipe. Plot graphs of the pressure within the pipe as a function of distance along the pipe for water depths of h = 1, 4, 10, and 25 m.



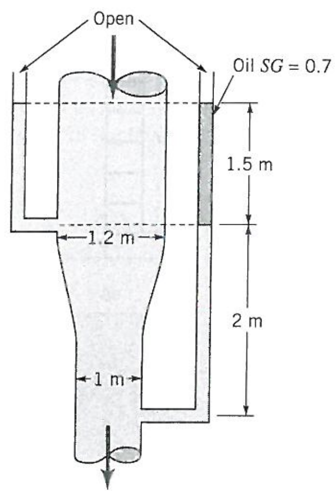
■ **Figure P3.79**

3.80 WILEY If viscous effects are neglected and the tank is large, determine the flowrate from the tank shown in Fig. P3.80.



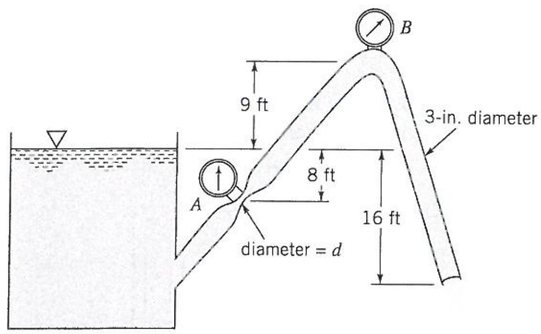
■ **Figure P3.80**

3.81 Water flows steadily downward in the pipe shown in Fig. P3.81 with negligible losses. Determine the flowrate.



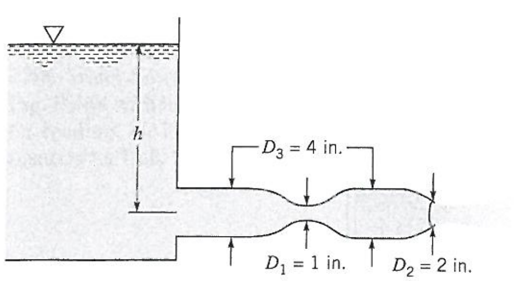
■ **Figure P3.81**

3.82 Water flows steadily from a large open tank and discharges into the atmosphere though a 3-in.-diameter pipe as shown in Fig. P3.82. Determine the diameter, d, in the narrowed section of the pipe at A if the pressure gages at A and B indicate the same pressure.



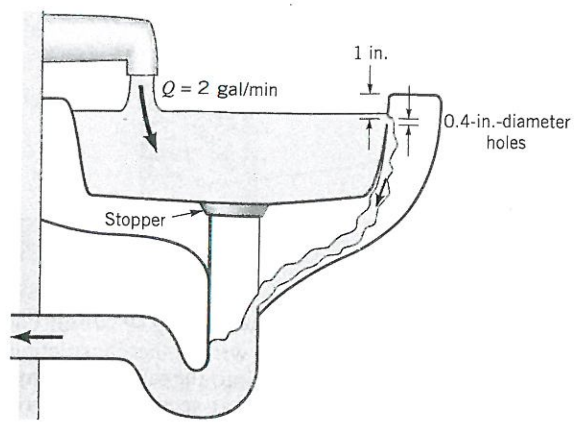
■ **Figure P3.82**

3.83 Water flows from a large tank as shown in Fig. P3.83. Atmospheric pressure is 14.5 psia, and the vapor pressure is 1.60 psia. If viscous effects are neglected, at what height, h, will cavitation begin? To avoid cavitation, should the value of D_1 be increased or decreased? To avoid cavitation, should the value of D_2 be increased or decreased? Explain.



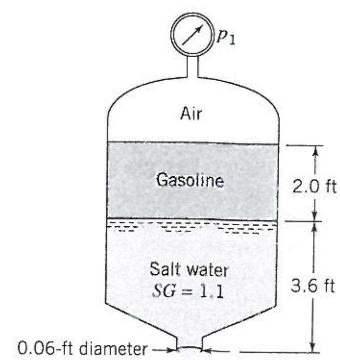
■ **Figure P3.83**

3.84 Water flows into the sink shown in Fig. P3.84 and **Video V5.1** at a rate of 2 gal/min. If the drain is closed, the water will eventually flow through the overflow drain holes rather than over the edge of the sink. How many 0.4-in.-diameter drain holes are needed to ensure that the water does not overflow the sink? Neglect viscous effects.



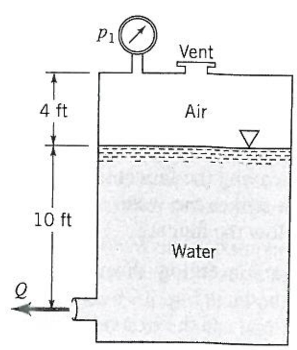
■ **Figure P3.84**

3.85 What pressure, p_1, is needed to produce a flowrate of 0.09 ft^3/s from the tank shown in Fig. P3.85?



■ **Figure P3.85**

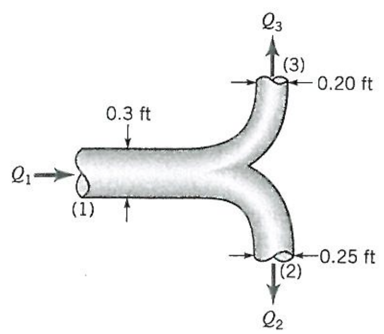
3.86 The vent on the tank shown in Fig. P3.86 is closed and the tank pressurized to increase the flowrate. What pressure, p_1, is needed to produce twice the flowrate of that when the vent is open?



■ **Figure P3.86**

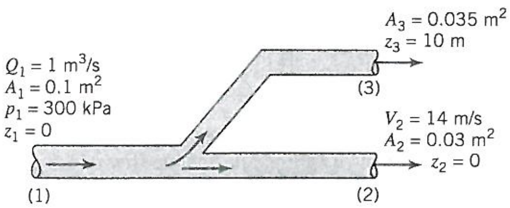
3.87 Water is siphoned from the tank shown in Fig. P3.87. Determine the flowrate from the tank and the pressures at points (1), (2), and (3) if viscous effects are negligible.

3.101 Water flows through the horizontal Y-fitting shown in Fig. P3.101. If the flowrate and pressure in pipe (1) are $Q_1 = 2.3\ \text{ft}^3/\text{s}$ and $p_1 = 50\ \text{lb/ft}^3$, determine the pressures p_2 and p_3, in pipes (2) and (3) under the assumption that the flowrate divides evenly between pipes (2) and (3).



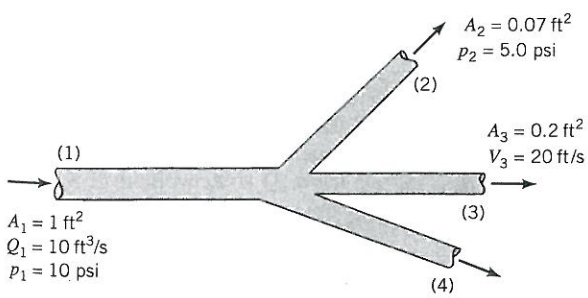
■ Figure P3.101

3.102 Water flows through the branching pipe shown in Fig. P3.102. If viscous effects are negligible, determine the pressure at section (2) and the pressure at section (3).



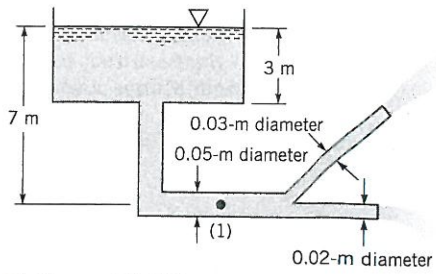
■ Figure P3.102

3.103 WILEY Water flows through the horizontal branching pipe shown in Fig. P3.103 at a rate of $10\ \text{ft}^3/\text{s}$. If viscous effects are negligible, determine the water speed at section (2), the pressure at section (3), and the flowrate at section (4).



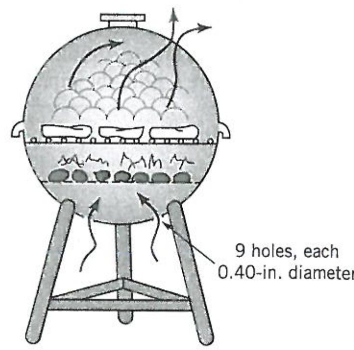
■ Figure P3.103

3.104 WILEY Water flows from a large tank through a large pipe that splits into two smaller pipes as shown in Fig. P3.104. If viscous effects are negligible, determine the flowrate from the tank and the pressure at point (1).



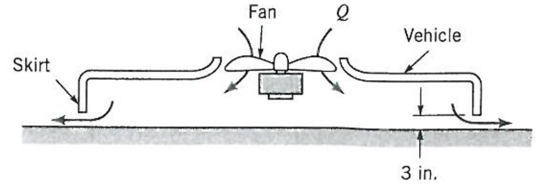
■ Figure P3.104

3.105 Air, assumed incompressible and inviscid, flows into the outdoor cooking grill through nine holes of 0.40-in. diameter as shown in Fig. P3.105. If a flowrate of 40 in.^{3}/s into the grill is required to maintain the correct cooking conditions, determine the pressure within the grill near the holes.



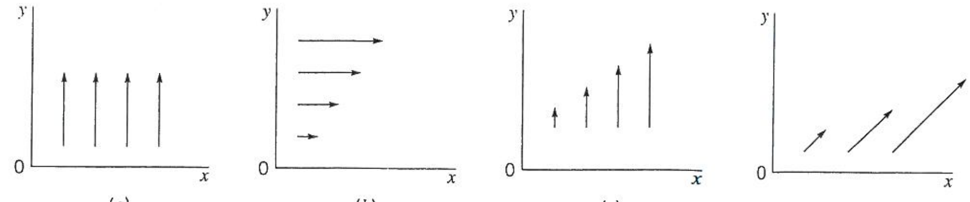
■ Figure P3.105

3.106 WILEY An air cushion vehicle is supported by forcing air into the chamber created by a skirt around the periphery of the vehicle as shown in Fig. P3.106. The air escapes through the 3-in. clearance between the lower end of the skirt and the ground (or water). Assume the vehicle weighs 10,000 lb and is essentially rectangular in shape, 30 by 65 ft. The volume of the chamber is large enough so that the kinetic energy of the air within the chamber is negligible. Determine the flowrate, Q, needed to support the vehicle. If the ground clearance were reduced to 2 in., what flowrate would be needed? If the vehicle weight were reduced to 5000 lb and the ground clearance maintained at 3 in., what flowrate would be needed?



■ Figure P3.106

3.107 WILEY Water flows from the pipe shown in Fig. P3.107 as a free jet and strikes a circular flat plate. The flow geometry shown is axisymmetrical. Determine the flowrate and the manometer reading, H.



(a) (b) (c) (d)

4.2C Consider the path of a football thrown by Brett Favre. Suppose that you are interested in determining how far the ball travels. Then you are interested in:

a) neither Lagrangian nor Eulerian views.

b) the Eulerian view of the field.

c) the Lagrangian or particle view of the football.

4.3C The following is true of the system (versus control volume) form of the basic equations (mass, momentum, angular momentum, and energy):

a) The equations apply to a fixed quantity of mass.

b) The equations are formulated in terms of extensive properties.

c) The equations apply to a fixed volume.

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 web site, www.wiley.com/college/munson.

Section 4.1 The Velocity Field

4.1 Obtain a photograph/image of a situation in which a fluid is flowing. Print this photo and draw in some lines to represent how you think some streamlines may look. Write a brief paragraph to describe the acceleration of a fluid particle as it flows along one of these streamlines.

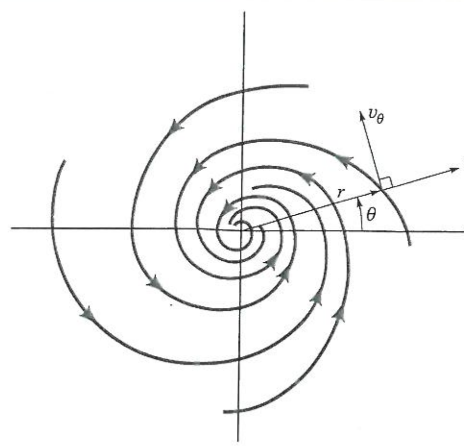
4.2 WILEY GO The velocity field of a flow is given by $\mathbf{V} = (3y + 2)\hat{\mathbf{i}} + (x - 8)\hat{\mathbf{j}} + 5z\hat{\mathbf{k}}$ ft/s , where x, y, and z are in feet. Determine the fluid speed at the origin ($x = y = z = 0$) and on the y axis ($x = z = 0$).

4.3 WILEY The velocity field of a flow is given by $\mathbf{V} = 2x^2t\hat{\mathbf{i}} + [4y(t - 1) + 2x^2t]\hat{\mathbf{j}}$ m/s, where x and y are in meters and t is in seconds. For fluid particles on the x axis, determine the speed and direction of flow.

4.4 A two-dimensional velocity field is given by $u = 1 + y$ and $v = 1$. Determine the equation of the streamline that passes through the origin. On a graph, plot this streamline.

4.5 WILEY The velocity field of a flow is given by $\mathbf{V} = (5z - 3)\hat{\mathbf{i}} + (x + 4)\hat{\mathbf{j}} + 4y\hat{\mathbf{k}}$ ft/s, where x, y, and z are in feet. Determine the fluid speed at the origin ($x = y = z = 0$) and on the x axis ($y = z = 0$).

4.6 WILEY A flow can be visualized by plotting the velocity field as velocity vectors at representative locations in the flow as shown in **Video V4.2** and Fig. E4.1. Consider the velocity field given in polar coordinates by $v_r = -10/r$, and $v_\theta = 10/r$. This flow approximates a fluid swirling into a sink as shown in Fig. P4.6. Plot the velocity field at locations given by $r = 1$, 2, and 3 with $\theta = 0$, 30, 60, and 90°.



■ **Figure P4.6**

4.7 WILEY The velocity field of a flow is given by $\mathbf{V} = 20y/(x^2 + y^2)^{1/2}\hat{\mathbf{i}} - 20x/(x^2 + y^2)^{1/2}\hat{\mathbf{j}}$ ft/s, where x and y are in feet. Determine the fluid speed at points along the x axis; along the y axis. What is the angle between the velocity vector and the x axis at points $(x, y) = (5, 0)$, $(5, 5)$, and $(0, 5)$?

4.8 WILEY The components of a velocity field are given by $u = x + y$, $v = xy^3 + 16$, and $w = 0$. Determine the location of any stagnation points ($\mathbf{V} = 0$) in the flow field.

4.9 WILEY The x and y components of velocity for a two-dimensional flow are $u = 6y$ ft/s and $v = 3$ ft/s, where y is in feet. Determine the equation for the streamlines and sketch representative streamlines in the upper half plane.

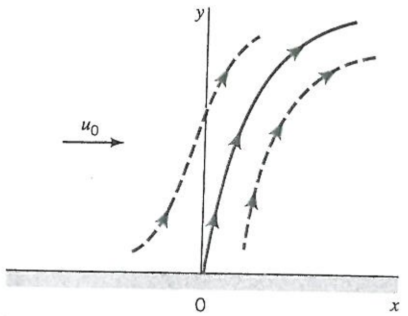
4.10 WILEY The velocity field of a flow is given by $u = -V_0y/(x^2 + y^2)^{1/2}$ and $v = V_0x/(x^2 + y^2)^{1/2}$, where V_0 is a constant. Where in the flow field is the speed equal to V_0? Determine the equation of the streamlines and discuss the various characteristics of this flow.

4.11 A velocity field is given by $\mathbf{V} = x\hat{\mathbf{i}} + x(x - 1)(y + 1)\hat{\mathbf{j}}$, where u and v are in ft/s and x and y are in feet. Plot the streamline that passes through $x = 0$ and $y = 0$. Compare this streamline with the streakline through the origin.

4.12 From time $t = 0$ to $t = 5$ hr radioactive steam is released from a nuclear power plant accident located at $x = -1$ mile and $y = 3$ miles. The following wind conditions are expected: $\mathbf{V} = 10\hat{\mathbf{i}} - 5\hat{\mathbf{j}}$ mph for $0 < t < 3$ hr, $\mathbf{V} = 15\hat{\mathbf{i}} + 8\hat{\mathbf{j}}$ mph for $3 < t < 10$ hr, and $\mathbf{V} = 5\hat{\mathbf{i}}$ mph for $t > 10$ hr. Draw to scale the expected streakline of the steam for $t = 3$, 10, and 15 hr.

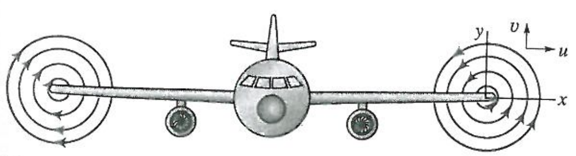
4.13 The x and y components of a velocity field are given by $u = x^2y$ and $v = -xy^2$. Determine the equation for the streamlines of this flow and compare it with those in Example 4.2. Is the flow in this problem the same as that in Example 4.2? Explain.

4.14 In addition to the customary horizontal velocity components of the air in the atmosphere (the "wind"), there often are vertical air currents (thermals) caused by buoyant effects due to uneven heating of the air as indicated in Fig. P4.14. Assume that the velocity field in a certain region is approximated by $u = u_0$, $v = v_0(1 - y/h)$ for $0 < y < h$, and $u = u_0$, $v = 0$ for $y > h$. Plot the shape of the streamline that passes through the origin for values of $u_0/v_0 = 0.5$, 1, and 2.



■ Figure P4.14

4.15 As shown in Video V4.6 and Fig. P4.15, a flying airplane produces swirling flow near the end of its wings. In certain circumstances this flow can be approximated by the velocity field $u = -Ky/(x^2 + y^2)$ and $v = Kx/(x^2 + y^2)$, where K is a constant depending on various parameters associated with the airplane (i.e., its weight, speed) and x and y are measured from the center of the swirl. **(a)** Show that for this flow the velocity is inversely proportional to the distance from the origin. That is, $V = K/(x^2 + y^2)^{1/2}$. **(b)** Show that the streamlines are circles.



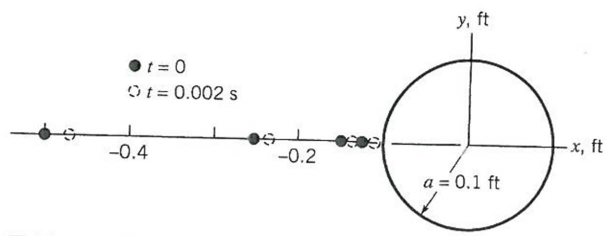
■ Figure P4.15

†4.16 For any steady flow the streamlines and streaklines are the same. For most unsteady flows this is not true. However, there are unsteady flows for which the streamlines and streaklines are the same. Describe a flow field for which this is true.

4.17 A 10-ft-diameter dust devil that rotates one revolution per second travels across the Martian surface (in the x-direction) with a speed of 5 ft/s. Plot the pathline etched on the surface by a fluid particle 10 ft from the center of the dust devil for time $0 \le t \le 3$ s. The particle position is given by the sum of that for a stationary swirl [$x = 10\cos(2\pi t)$, $y = 10\sin(2\pi t)$] and that for a uniform velocity ($x = 5t$, $y =$ constant), where x and y are in feet and t is in seconds.

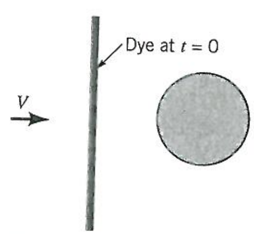
4.18 (See Fluids in the News article titled "Follow those particles," Section 4.1.) Two photographs of four particles in a flow past a sphere are superposed as shown in Fig. P4.18. The time interval between the photos is $\Delta t = 0.002$ s. The locations of the particles, as determined from the photos, are shown in the table. **(a)** Determine the fluid velocity for these particles. **(b)** Plot a graph to compare the results of part **(a)** with the theoretical velocity which is given by $V = V_0(1 + a^3/x^3)$, where a is the sphere radius and V_0 is the fluid speed far from the sphere.

Particle	x at $t = 0$ s (ft)	x at $t = 0.002$ s (ft)
1	−0.500	−0.480
2	−0.250	−0.232
3	−0.140	−0.128
4	−0.120	−0.112



■ Figure P4.18

†4.19 Pathlines and streaklines provide ways to visualize flows. Another technique would be to instantly inject a line of dye across streamlines and observe how this line moves as time increases. For example, consider the initially straight dye line injected in front of the circular cylinder shown in Fig. P4.19. Discuss how this dye line would appear at later times. How would you calculate the location of this line as a function of time?



■ Figure P4.19

Section 4.2 The Acceleration Field

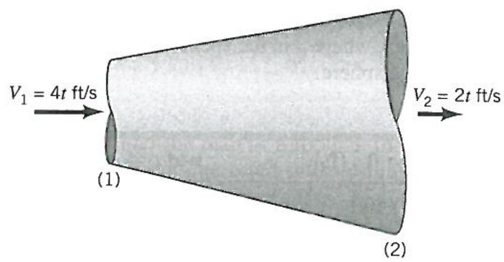
4.20 A velocity field is given by $u = cx^2$ and $v = cy^2$, where c is a constant. Determine the x and y components of the acceleration. At what point (points) in the flow field is the acceleration zero?

4.21 Determine the acceleration field for a three-dimensional flow with velocity components $u = -x$, $v = 4x^2y^2$, and $w = x - y$.

4.22 A three-dimensional velocity field is given by $u = 2x$, $v = -y$, and $w = z$. Determine the acceleration vector.

4.23 Water flows through a constant diameter pipe with a uniform velocity given by $\mathbf{V} = (8/t + 5)\hat{\mathbf{j}}$ m/s, where t is in seconds. Determine the acceleration at time $t = 1$, 2, and 10 s.

4.24 WILEY The velocity of air in the diverging pipe shown in Fig. P4.24 is given by $V_1 = 4t$ ft/s and $V_2 = 2t$ ft/s, where t is in seconds. **(a)** Determine the local acceleration at points (1) and (2). **(b)** Is the average convective acceleration between these two points negative, zero, or positive? Explain.

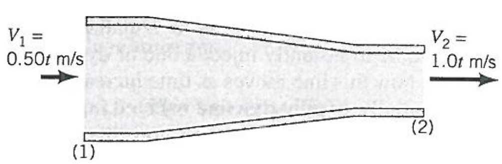


■ **Figure P4.24**

4.25 WILEY Water flows in a pipe so that its velocity triples every 20 s. At $t = 0$ it has $u = 5$ ft/s. That is, $\mathbf{V} = u(t)\hat{\mathbf{i}} = 5\,(3^{t/20})\hat{\mathbf{i}}$ ft/s. Determine the acceleration when $t = 0$, 10, and 20 s.

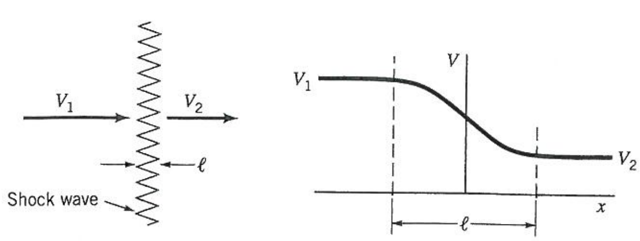
4.26 WILEY When a valve is opened, the velocity of water in a certain pipe is given by $u = 10(1 - e^{-t})$, $v = 0$, and $w = 0$, where u is in ft/s and t is in seconds. Determine the maximum velocity and maximum acceleration of the water.

4.27 WILEY The velocity of the water in the pipe shown in Fig. P4.27 is given by $V_1 = 0.50t$ m/s and $V_2 = 1.0t$ m/s, where t is in seconds. Determine the local acceleration at points (1) and (2). Is the average convective acceleration between these two points negative, zero, or positive? Explain.



■ **Figure P4.27**

4.28 WILEY A shock wave is a very thin layer (thickness $= \ell$) in a high-speed (supersonic) gas flow across which the flow properties (velocity, density, pressure, etc.) change from state (1) to state (2) as shown in Fig. P4.28. If $V_1 = 1800$ fps, $V_2 = 700$ fps, and $\ell = 10^{-4}$ in., estimate the average deceleration of the gas as it flows across the shock wave. How many g's deceleration does this represent?

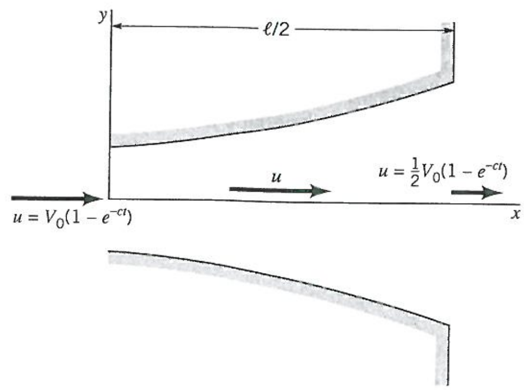


■ **Figure P4.28**

†4.29 Estimate the average acceleration of water as it travels through the nozzle on your garden hose. List all assumptions and show all calculations.

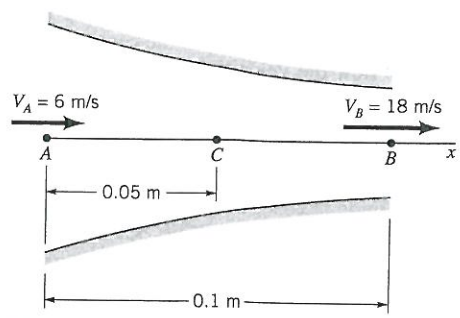
†4.30 A stream of water from the faucet strikes the bottom of the sink. Estimate the maximum acceleration experienced by the water particles. List all assumptions and show calculations.

4.31 WILEY As a valve is opened, water flows through the diffuser shown in Fig. P4.31 at an increasing flowrate so that the velocity along the centerline is given by $\mathbf{V} = u\hat{\mathbf{i}} = V_0(1 - e^{-ct})(1 - x/\ell)\,\hat{\mathbf{i}}$, where u_0, c, and ℓ are constants. Determine the acceleration as a function of x and t. If $V_0 = 10$ ft/s and $\ell = 5$ ft, what value of c (other than $c = 0$) is needed to make the acceleration zero for any x at $t = 1$ s? Explain how the acceleration can be zero if the flowrate is increasing with time.



■ **Figure P4.31**

4.32 The fluid velocity along the x axis shown in Fig. P4.32 changes from 6 m/s at point A to 18 m/s at point B. It is also known that the velocity is a linear function of distance along the streamline. Determine the acceleration at points A, B, and C. Assume steady flow.



■ **Figure P4.32**

4.33 WILEY A fluid flows along the x axis with a velocity given by $\mathbf{V} = (x/t)\,\hat{\mathbf{i}}$, where x is in feet and t in seconds. **(a)** Plot the speed for $0 \le x \le 10$ ft and $t = 3$ s. **(b)** Plot the speed for $x = 7$ ft and $2 \le t \le 4$ s. **(c)** Determine the local and convective acceleration. **(d)** Show that the acceleration of any fluid particle in the flow is zero. **(e)** Explain physically how the velocity of a particle in this unsteady flow remains constant throughout its motion.

4.34 WILEY A hydraulic jump is a rather sudden change in depth of a liquid layer as it flows in an open channel as shown in Fig. P4.34 and **Video V10.12**. In a relatively short distance