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References

1. Riley, W. F., and Sturges, L. D., *Engineering Mechanics: Dynamics,* 2nd Ed., Wiley, New York, 1996.
2. Tipler, P. A., *Physics,* Worth, New York, 1982.
3. Panton, R. L., *Incompressible Flow,* Wiley, New York, 1984.

Problem available in *WileyPLUS* at instructor's discretion.

Tutoring problem available in *WileyPLUS* at instructor's discretion.

Problem is related to a chapter video available in *WileyPLUS*.

* Problem to be solved with aid of programmable calculator or computer.

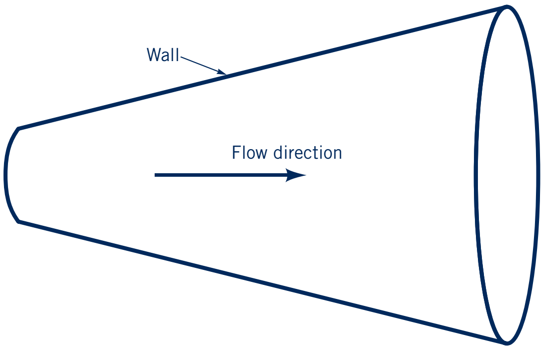
† Open-ended problem that requires critical thinking. These problems require various assumptions to provide the necessary input data. There are not unique answers to these problems.

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

3.1C In low-speed flow, the following device is called a diffuser:



The fluid velocity:

a) increases in the direction of flow.

b) decreases in the direction of flow.

c) stays the same in the direction of flow.

d) None of the above.

3.2C Consider constant altitude, steady flow along a streamline with a flow that satisfies the assumptions necessary for Bernoulli's equation. Which of the following have a constant value along the streamline?

a) Internal energy

b) Static or local pressure

c) Stagnation or total pressure

d) Dynamic or velocity pressure

3.3C The stagnation pressure for a fluid is

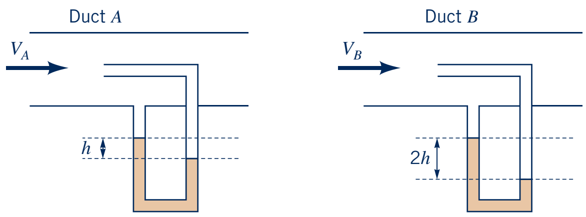
a) the pressure due to the velocity of the fluid.

b) not defined unless the fluid is moving.

c) the total pressure when the fluid is brought to rest.

d) the sum of the static and dynamic pressures.

3.4C Pitot tubes are placed in two ducts in which air is flowing and the static pressures of the flows are equal. The stagnation pressure tap and the static pressure tap are connected to manometers as shown. The manometer reading for duct A is height h, and that for duct B is 2h. The relation between the velocity V_A in duct A and the velocity V_B in duct B is



a) V_B equals $V_A/2$.

b) V_B equals $\sqrt{2}V_A$.

c) V_B equals $4V_A$.

d) V_B equals $2V_A$.

e) V_B equals V_A.

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 3.2 F = *m*a along a Streamline

3.1 Obtain a photograph/image of a situation that can be analyzed by use of the Bernoulli equation. Print this photo and write a brief paragraph that describes the situation involved.

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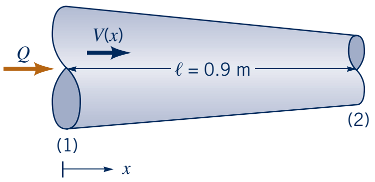
3.2 Air flows steadily along a streamline from point (1) to point (2) with negligible viscous effects. The following conditions are measured: At point (1) $z_1 = 2$ m and $p_1 = 0$ kPa; at point (2) $z_2 = 10$ m, $p_2 = 20$ N/m^2, and $V_2 = 0$. Determine the velocity at point (1).

3.3 WILEY Water flows steadily through the variable area horizontal pipe shown in Fig. P3.3. The centerline velocity is given by $\mathbf{V} = 3(1 + 3x)\,\hat{\mathbf{i}}$ m/s, where x is in meters. Viscous effects are neglected. **(a)** Determine the pressure gradient, $\partial p/\partial x$, (as a function of x) needed to produce this flow. **(b)** If the pressure at section (1) is 345 kPa, determine the pressure at (2) by (i) integration of the pressure gradient obtained in **(a)**, (ii) application of the Bernoulli equation.



■ **Figure P3.3**

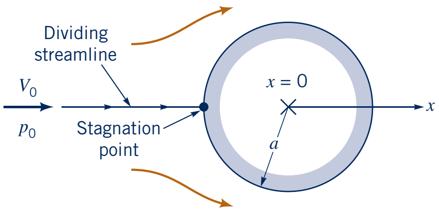
3.4 WILEY What pressure gradient along the streamline, dp/ds, is required to accelerate water in a horizontal pipe at a rate of 30 m/s^2?

3.5 WILEY GO At a given location, the airspeed is 20 m/s and the pressure gradient along the streamline is 100 N/m^3. Estimate the airspeed at a point 0.5 m farther along the streamline.

3.6 WILEY What pressure gradient along the streamline, dp/ds, is required to accelerate water upward in a vertical pipe at a rate of 9 m/s^2? What is the answer if the flow is downward?

3.7 The Bernoulli equation is valid for steady, inviscid, incompressible flows with constant acceleration of gravity. Consider flow on a planet where the acceleration of gravity varies with height so that $g = g_0 - cz$, where g_0 and c are constants. Integrate "$\mathbf{F} = m\mathbf{a}$" along a streamline to obtain the equivalent of the Bernoulli equation for this flow.

3.8 An incompressible fluid flows steadily past a circular cylinder as shown in Fig. P3.8. The fluid velocity along the dividing streamline $(-\infty \leq x \leq -a)$ is found to be $V = V_0(1 - a^2/x^2)$, where a is the radius of the cylinder and V_0 is the upstream velocity. **(a)** Determine the pressure gradient along this streamline. **(b)** If the upstream pressure is p_0, integrate the pressure gradient to obtain the pressure $p(x)$ for $-\infty \leq x \leq -a$. **(c)** Show from the result of part **(b)** that the pressure at the stagnation point $(x = -a)$ is $p_0 + \rho V_0^2/2$, as expected from the Bernoulli equation.



■ **Figure P3.8**

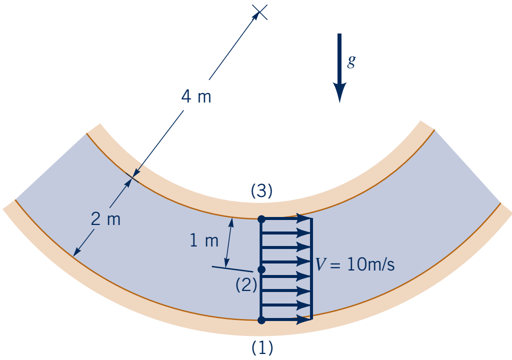
3.9 Consider a compressible liquid that has a constant bulk modulus. Integrate "$\mathbf{F} = m\mathbf{a}$" along a streamline to obtain the equivalent of the Bernoulli equation for this flow. Assume steady, inviscid flow.

Section 3.3 F = ma Normal to a Streamline

3.10 Obtain a photograph/image of a situation in which Newton's second law applied across the streamlines (as given by Eq. 3.12) is important. Print this photo and write a brief paragraph that describes the situation involved.

3.11 WILEY Air flows along a horizontal, curved streamline with a 60 m radius with a speed of 30 m/s. Determine the pressure gradient normal to the streamline.

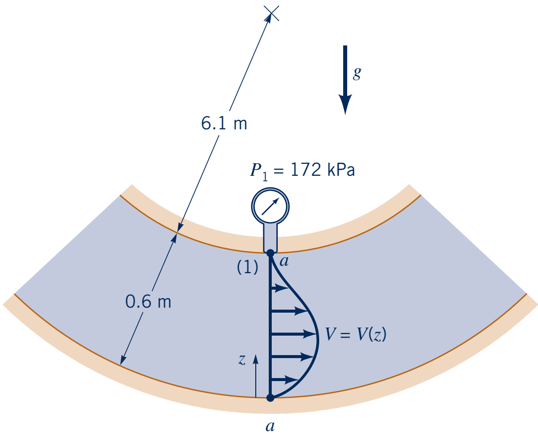
3.12 WILEY Water flows around the vertical two-dimensional bend with circular streamlines and constant velocity as shown in Fig. P3.12. If the pressure is 40 kPa at point (1), determine the pressures at points (2) and (3). Assume that the velocity profile is uniform as indicated.



■ **Figure P3.12**

3.13 WILEY Water flows around the vertical two-dimensional bend with circular streamlines as is shown in Fig. P3.13. The pressure at point (1) is measured to be $p_1 = 172$ kPa and the velocity across section a–a is as indicated in the table. Calculate and plot the pressure across section a–a of the channel [$p = p(z)$ for $0 \leq z \leq 0.6$ m].

z (m)	V (m/s)
0	0
0.06	2.4
0.12	4.4
0.18	6.0
0.24	5.9
0.30	4.8
0.36	2.5
0.42	1.9
0.48	1.1
0.54	0.6
0.60	0



■ **Figure P3.13**

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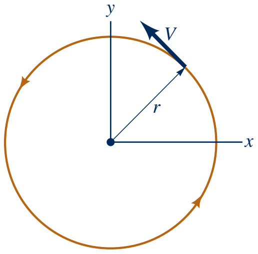
3.14 Water in a container and air in a tornado flow in horizontal circular streamlines of radius r and speed V as shown in **Video V3.6** and Fig. P3.14. Determine the radial pressure gradient, $\partial p/\partial r$, needed for the following situations: **(a)** The fluid is water with $r = 0.08$ cm and $V = 0.02$ m/s. **(b)** The fluid is air with $r = 7.6$ m and $V = 322$ km/h.



■ **Figure P3.14**

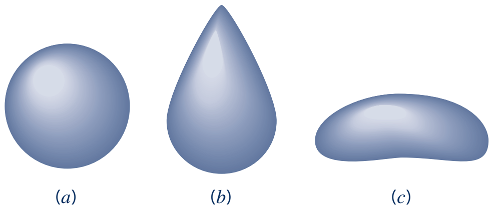
3.15 Air flows smoothly over the hood of your car and up past the windshield. However, a bug in the air does not follow the same path; it becomes splattered against the windshield. Explain why this is so.

Section 3.5 Static, Stagnation, Dynamic, and Total Pressure

3.16 Obtain a photograph/image of a situation in which the concept of the stagnation pressure is important. Print this photo and write a brief paragraph that describes the situation involved.

3.17 At a given point on a horizontal streamline in flowing air, the static pressure is −13.8 kPa (i.e., a vacuum) and the velocity is 46 m/s. Determine the pressure at a stagnation point on that streamline.

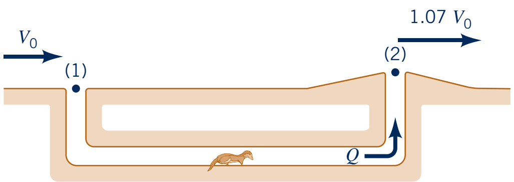
†3.18 A drop of water in a zero-g environment (as in the International Space Station) will assume a spherical shape as shown in Fig. P3.18*a*. A raindrop in the cartoons is typically drawn as in Fig. P3.18*b*. The shape of an actual raindrop is more nearly like that shown in Fig. 3.18*c*. Discuss why these shapes are as indicated.



■ **Figure P3.18**

3.19 When an airplane is flying 322 km/h at 1524 m altitude in a standard atmosphere, the air velocity at a certain point on the wing is 439 km/h relative to the airplane. **(a)** What suction pressure is developed on the wing at that point? **(b)** What is the pressure at the leading edge (a stagnation point) of the wing?

3.20 Some animals have learned to take advantage of the Bernoulli effect without having read a fluid mechanics book. For example, a typical prairie dog burrow contains two entrances—a flat front door and a mounded back door as shown in Fig. P3.20. When the wind blows with velocity V_0 across the front door, the average velocity across the back door is greater than V_0 because of the mound. Assume the air velocity across the back door is $1.07V_0$. For a wind velocity of 6 m/s, what pressure differences, $p_1 - p_2$, are generated to provide a fresh airflow within the burrow?



■ **Figure P3.20**

3.21 A loon is a diving bird equally at home "flying" in the air or water. What swimming velocity under water will produce a dynamic pressure equal to that when it flies in the air at 64 km/h?

†3.22 Estimate the pressure on your hand when you hold it in the stream of air coming from the air hose at a filling station. List all assumptions and show calculations. Warning: Do not try this experiment; it can be dangerous!

3.23 A person holds her hand out of an open car window while the car drives through still air at 105 km/h. Under standard atmospheric conditions, what is the maximum pressure on her hand? What would be the maximum pressure if the "car" were an Indy 500 racer traveling 354 km/h?

3.24 A Pitot-static tube is used to measure the velocity of helium in a pipe. The temperature and pressure are 4.4 °C and 172 kPa. A water manometer connected to the Pitot-static tube indicates a reading of 5.8 cm. Determine the helium velocity. Is it reasonable to consider the flow as incompressible? Explain.

3.25 A Bourdon-type pressure gage is used to measure the pressure from a Pitot tube attached to the leading edge of an airplane wing. The gage is calibrated to read in kilometers per hour at standard sea level conditions. If the airspeed meter indicates 241.4 km/h when flying at an altitude of 3048 m, what is the true airspeed?

†3.26 Estimate the force of a hurricane strength wind against the side of your house. List any assumptions and show all calculations.

3.27 A 64 km/h wind blowing past your house speeds up as it flows up and over the roof. If elevation effects are negligible, determine **(a)** the pressure at the point on the roof where the speed is 96.6 km/h if the pressure in the free stream blowing toward your house is 101.3 kPa. Would this effect tend to push the roof down against the house, or would it tend to lift the roof? **(b)** Determine the pressure on a window facing the wind if the window is assumed to be a stagnation point.

3.28 (See Fluids in the News article titled **"Pressurized eyes,"** Section 3.5.) Determine the air velocity needed to produce a stagnation pressure equal to 10 mm of mercury.

Section 3.6.1 Free Jets

3.29 Water flows through a hole in the bottom of a large, open tank with a speed of 8 m/s. Determine the depth of water in the tank. Viscous effects are negligible.

†3.30 Estimate the pressure needed at the pumper truck in order to shoot water from the street level onto a fire on the roof of a five-story building. List all assumptions and show all calculations.

3.31 Water flows from the faucet on the first floor of the building shown in Fig. P3.31 with a maximum velocity of 6 m/s. For steady inviscid flow, determine the maximum water velocity

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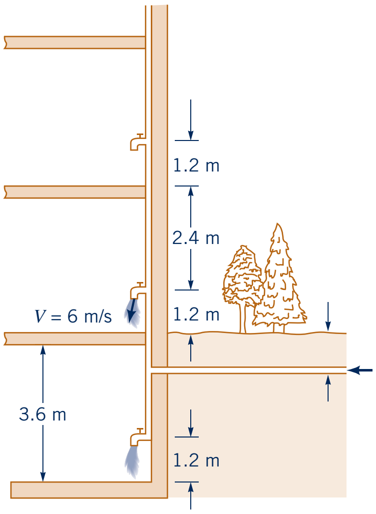
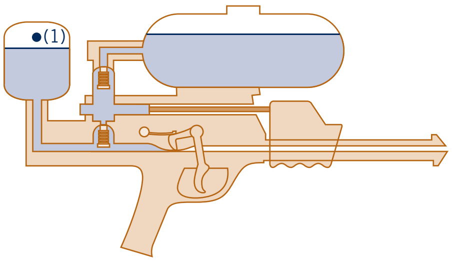
from the basement faucet and from the faucet on the second floor (assume each floor is 3.6 m tall).



■ **Figure P3.31**

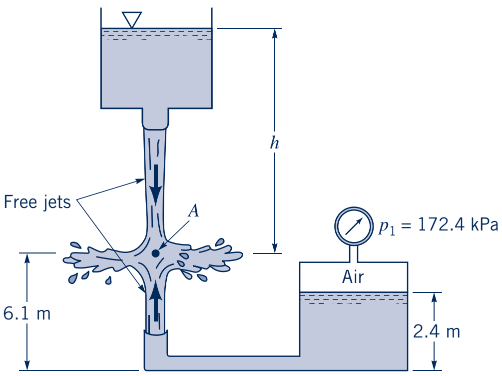
3.32 Laboratories containing dangerous materials are often kept at a pressure slightly less than ambient pressure so that contaminants can be filtered through an exhaust system rather than leaked through cracks around doors, etc. If the pressure in such a room is 0.254 cm of water below that of the surrounding 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 9 m 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.



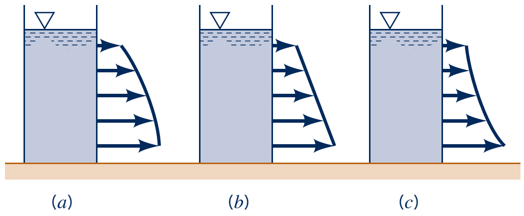
■ **Figure P3.33**

3.34 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*.



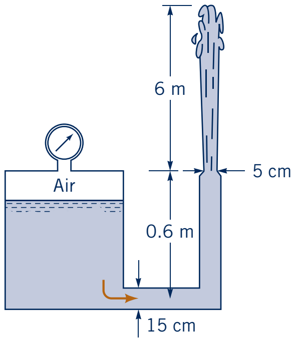
■ **Figure P3.34**

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.



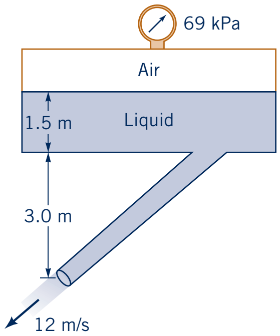
■ **Figure P3.35**

3.36 Water flows from a pressurized tank, through a 15 cm diameter pipe, exits from a 5 cm diameter nozzle, and rises 6 m 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 An inviscid, incompressible liquid flows steadily from the large pressurized tank shown in Fig. P.3.37. The velocity at the exit is 12 m/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 10.2 cm diameter pipe and exits into the atmosphere through a 7.6 cm diameter nozzle. The velocity at the nozzle exit is 45.72 m/s. Determine the pressure in the pipe if viscous effects are negligible.

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3.40 For the pipe enlargement shown in Fig. P3.40, the pressures at sections (1) and (2) are 388.2 kPa and 401.3 kPa, respectively. Determine the weight flowrate (N/s) of the gasoline in the pipe.

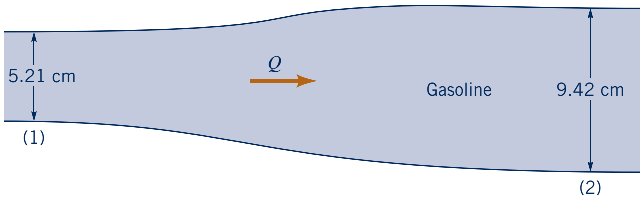

Figure P3.40

3.41 WILEY GO A fire hose nozzle has a diameter of 2.86 cm. According to some fire codes, the nozzle must be capable of delivering at least 946 L/min. If the nozzle is attached to a 7.62 cm diameter hose, what pressure must be maintained just upstream of the nozzle to deliver this flowrate?

3.42 WILEY Water flowing from the 1.90 cm diameter outlet shown in **Video V8.15** and Fig. P3.42 rises 7.1 cm above the outlet. Determine the flowrate.

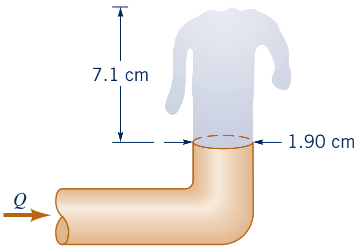

Figure P3.42

3.43 Pop (with the same properties as water) flows from a 10.16 cm diameter pop container that contains three holes as shown in Fig. P3.43 (see **Video 3.9**). The diameter of each fluid stream is 0.38 cm and the distance between holes is 5.08 cm. 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 5.08 cm above the top hole when $t = 0$. Compare your results with the time you measure from the video.

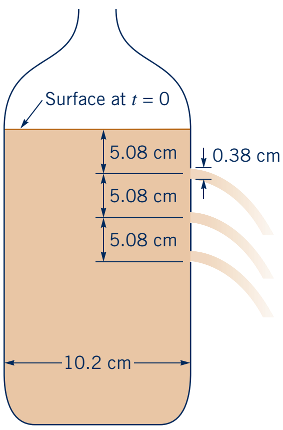

Figure P3.43

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

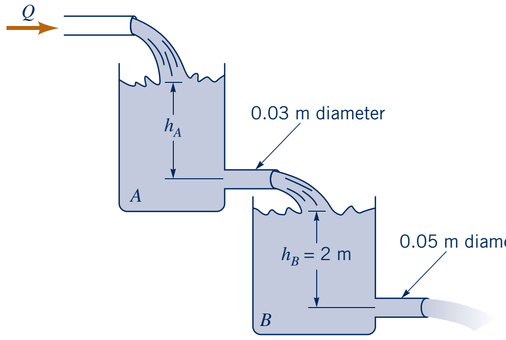

Figure P3.44

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.

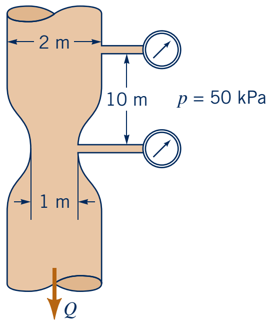

Figure P3.45

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 97 km/h. Note that there is a 2.5 cm 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.

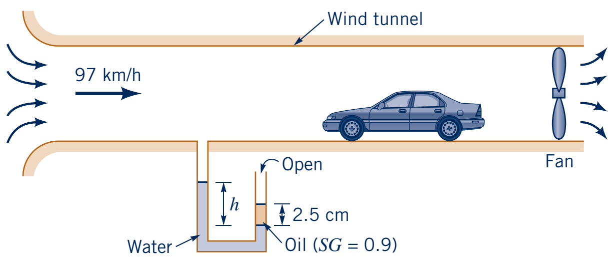

Figure P3.46

3.47 Natural gas (methane) flows from a 7.6 cm diameter gas main, through a 2.5 cm diameter pipe, and into the burner of a furnace at a rate of 2.8 m^3/h. Determine the pressure in the gas main if the pressure in the 2.5 cm pipe is to be 15.2 cm 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

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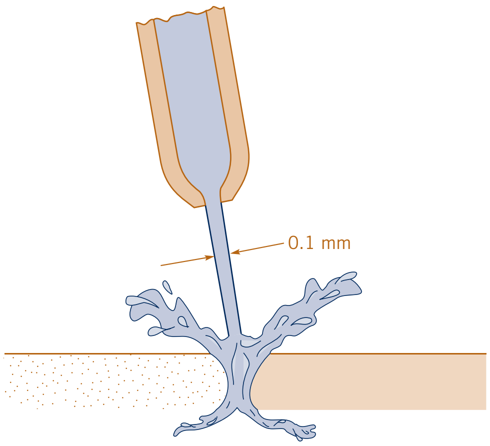
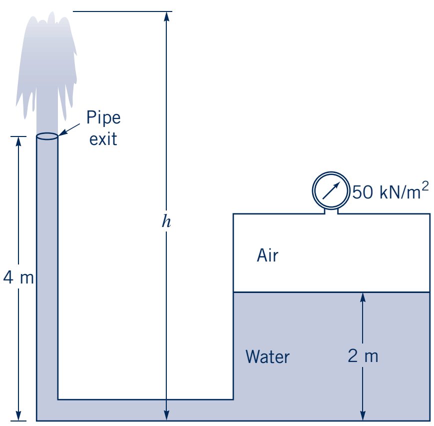
0.10 mm diameter water jet with a speed of 700 m/s. Determine the flowrate.



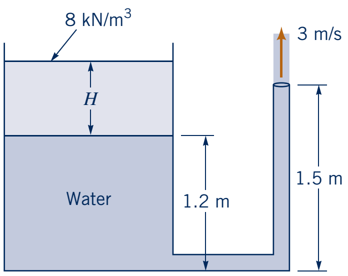
■ **Figure P3.48**

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/m². 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.



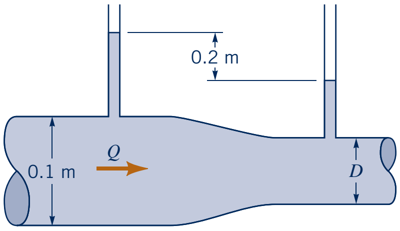
■ **Figure P3.49**

3.50 Water (assumed inviscid and incompressible) flows steadily with a speed of 3 m/s from the large tank shown in Fig. P3.50. Determine the depth, *H*, of the layer of light liquid (specific weight = 8 kN/m³) that covers the water in the tank.



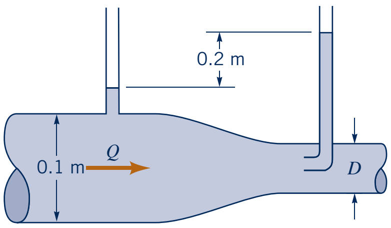
■ **Figure P3.50**

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*.

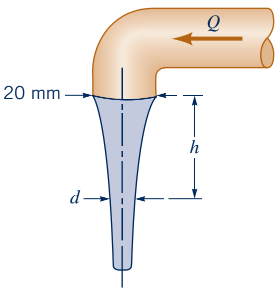


■ **Figure P3.52**

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 m³/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 138 kPa and 9 m/s, respectively. At location *B* the pressure and velocity are 159 kPa and 4 m/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 $0 \le Q \le 0.004$ m³/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

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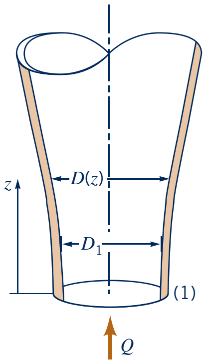
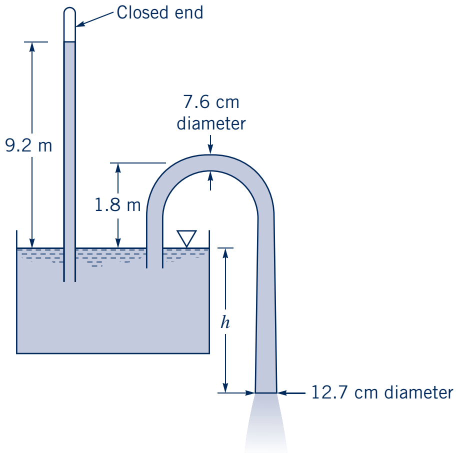
negligible, determine the diameter, $D(z)$, in terms of D_1 if the pressure is to remain constant throughout the pipe. That is, $p(z) = p_1$.



■ **Figure P3.56**

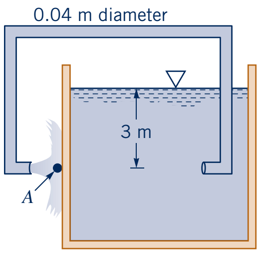
3.57 WILEY The circular stream of water from a faucet is observed to taper from a diameter of 20 mm to 10 mm in a distance of 50 cm. Determine the flowrate.

3.58 WILEY GO Water is siphoned from the tank shown in Fig. P3.58. The water barometer indicates a reading of 9.2 m. 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.



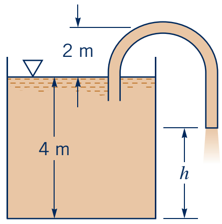
■ **Figure P3.58**

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.



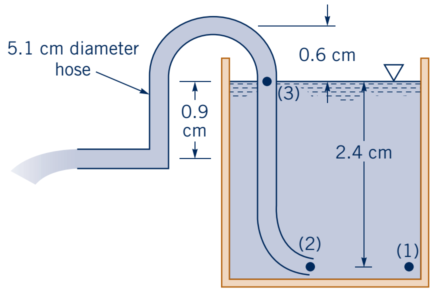
■ **Figure P3.59**

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**

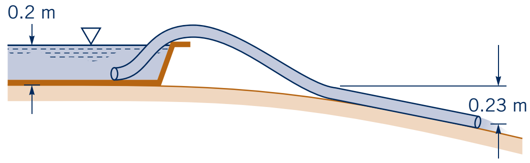
3.61 Water is siphoned from the tank shown in Fig. P3.61. Determine the flowrate from the tank and the pressure at points (1), (2), and (3) if viscous effects are negligible.



■ **Figure P3.61**

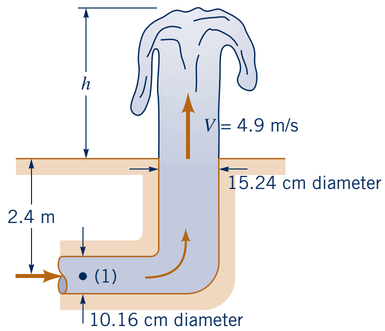
3.62 Redo Problem 3.61 if a 2.5 cm diameter nozzle is placed at the end of the tube.

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**

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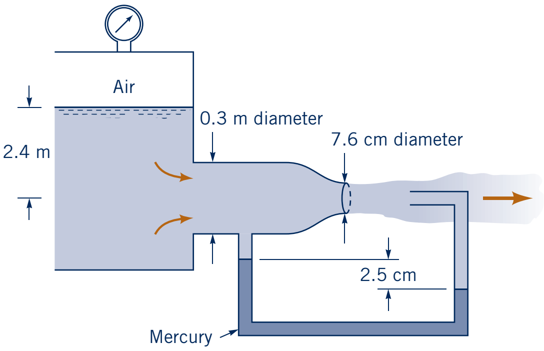
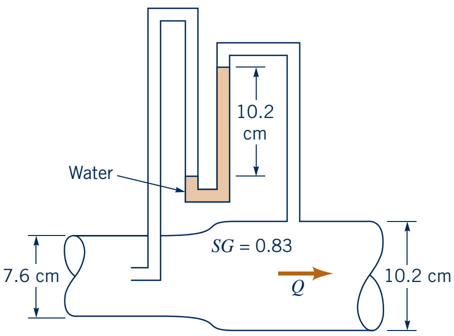
3.65 Water flows steadily from a large, closed tank as shown in Fig. P3.65. The deflection in the mercury manometer is 2.5 cm and viscous effects are negligible. **(a)** Determine the volume flowrate. **(b)** Determine the air pressure in the space above the surface of the water in the tank.



■ **Figure P3.65**

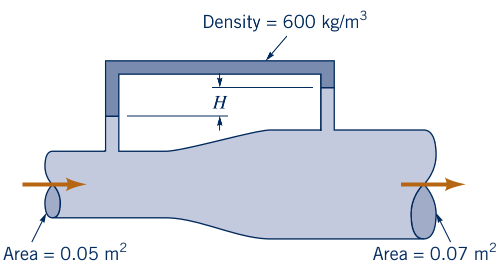
3.66 Carbon dioxide flows at a rate of 4.2×10^{-2} m^3/s from a 7.6 m pipe in which the pressure and temperature are 138 kPa (gage) and 49 °C into a 3.8 cm pipe. If viscous effects are neglected and incompressible conditions are assumed, determine the pressure in the smaller pipe.

3.67 Oil of specific gravity 0.83 flows in the pipe shown in Fig. P3.67. If viscous effects are neglected, what is the flowrate?



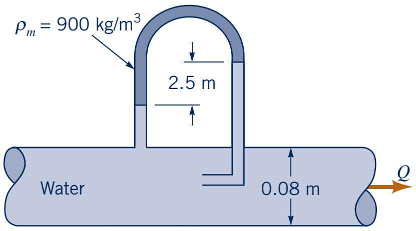
■ **Figure P3.67**

3.68 Water flows steadily through the variable area pipe shown in Fig. P3.68 with negligible viscous effects. Determine the manometer reading, H, if the flowrate is 0.5 m^3/s and the density of the manometer fluid is 600 kg/m^3.



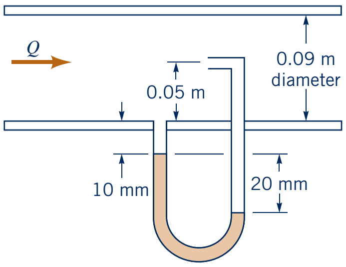
■ **Figure P3.68**

3.69 Determine the flowrate through the pipe in Fig. P3.69.



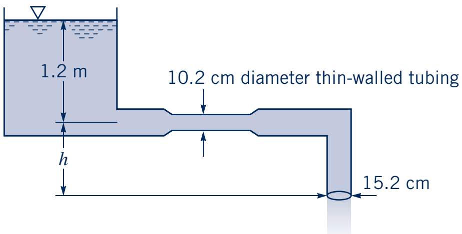
■ **Figure P3.69**

3.70 The specific gravity of the manometer fluid shown in Fig. P3.70 is 1.07. Determine the volume flowrate, Q, if the flow is inviscid and incompressible and the flowing fluid is **(a)** water, **(b)** gasoline, or **(c)** air at standard conditions.



■ **Figure P3.70**

3.71 Water flows steadily with negligible viscous effects through the pipe shown in Fig. P3.71. It is known that the 10.2 cm diameter section of thin-walled tubing will collapse if the pressure within it becomes less than 69 kPa below atmospheric pressure. Determine the maximum value that h can have without causing collapse of the tubing.



■ **Figure P3.71**

3.72 Helium flows through a 0.30 m diameter horizontal pipe with a temperature of 20 °C and a pressure of 200 kPa (abs) at a rate of 0.30 kg/s. If the pipe reduces to 0.25 m diameter, determine the pressure difference between these two sections. Assume incompressible, inviscid flow.

3.73 Water is pumped from a lake through a 20.32 cm pipe at a rate of 2.8 m^3/s. If viscous effects are negligible, what is the pressure in the suction pipe (the pipe between the lake and the pump) at an elevation 1.8 m above the lake?

3.74 Air is drawn into a small open-circuit wing tunnel as shown in Fig. P3.74. Atmospheric pressure is 98.7 kPa (abs) and the temperature is 27 °C. If viscous effects are negligible, determine the pressure at the stagnation point on the nose of the airplane. Also determine the manometer reading, h, for the manometer attached to the static pressure tap within the test section of the wind tunnel if the air velocity within the test section is 50 m/s.

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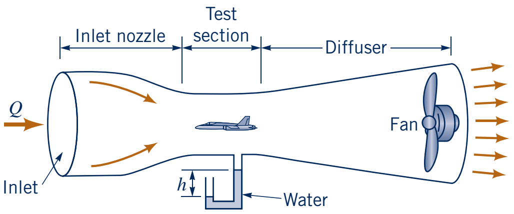
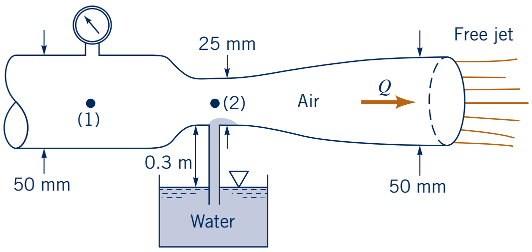


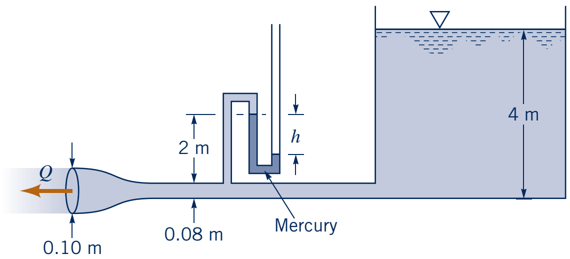
■ **Figure P3.74**

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**

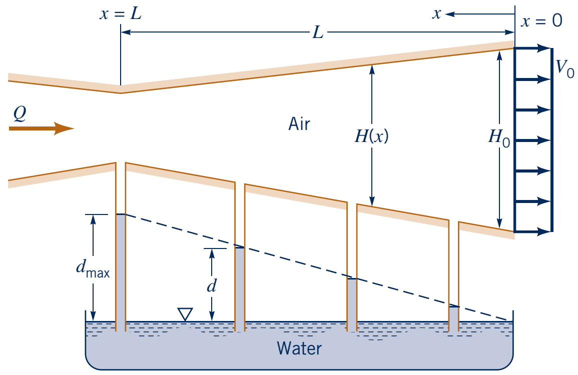
3.76 WILEY Water flows steadily from the large open tank shown in Fig. 3.76. If viscous effects are negligible, determine **(a)** the flowrate, Q, and **(b)** the manometer reading, h.



■ **Figure P3.76**

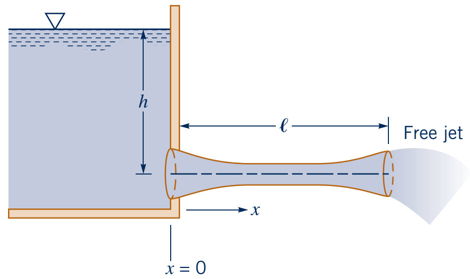
3.77 WILEY Water from a faucet fills a 0.5 L glass (volume = 5×10^{-4} m^3) in 20 s. If the diameter of the jet leaving the faucet is 15.2 cm what is the diameter of the jet when it strikes the water surface in the glass which is positioned 35.6 cm below the faucet?

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.



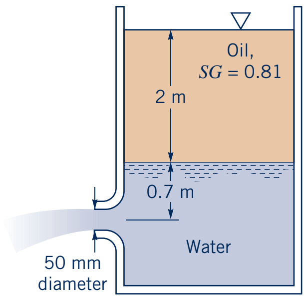
■ **Figure P3.78**

***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. P.3.81 with negligible losses. Determine the flowrate.

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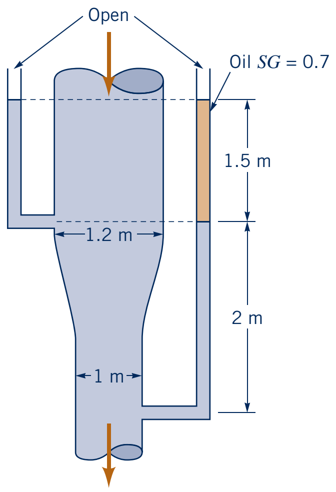
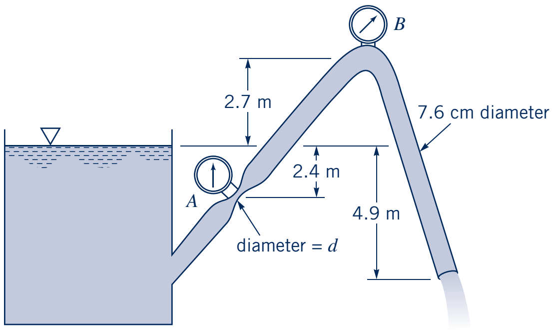


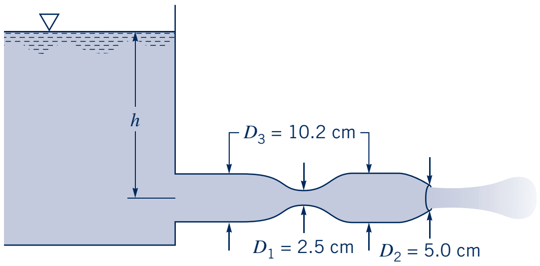
■ **Figure P3.81**

3.82 Water flows steadily from a large open tank and discharges into the atmosphere through a 7.6 cm 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.



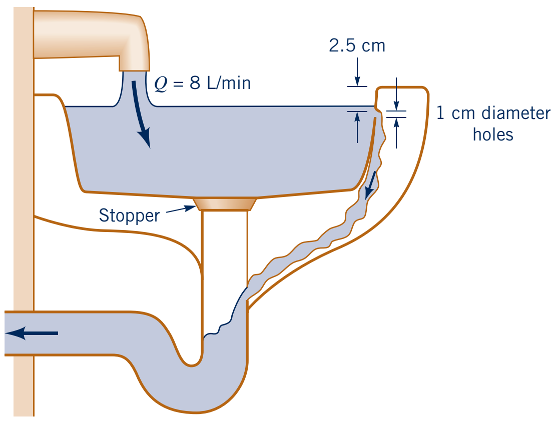
■ **Figure P3.82**

3.83 WILEY Water flows from a large tank as shown in Fig. P3.83. Atmospheric pressure is 100 kPa and the vapor pressure is 11.06 kPa. 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.



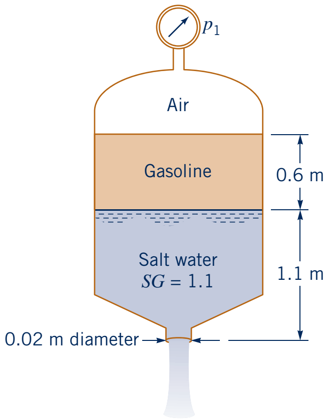
■ **Figure P3.83**

3.84 WILEY Water flows into the sink shown in Fig. P3.84 and **Video V5.1** at a rate of 8 L/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 1.0 cm diameter drain holes are needed to ensure that the water does not overflow the sink? Neglect viscous effects.



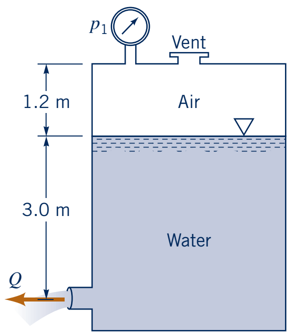
■ **Figure P3.84**

3.85 WILEY What pressure, p_1, is needed to produce a flowrate of 2.5×10^{-3} m^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 WILEY 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.

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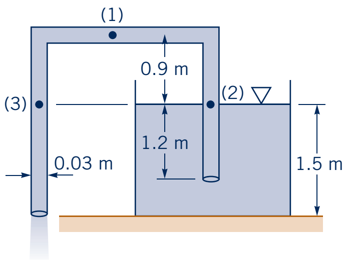
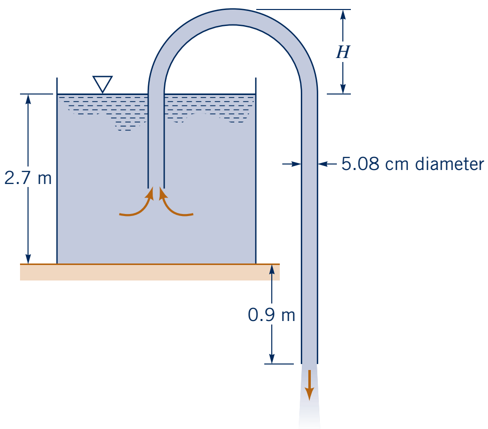


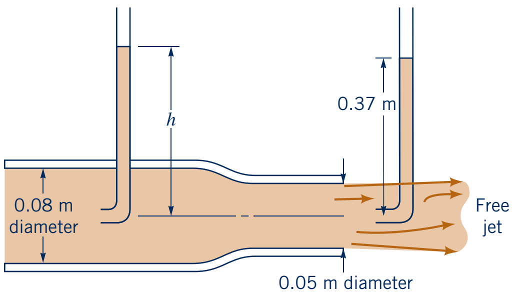
■ **Figure P3.87**

3.88 Water is siphoned from a large tank and discharges into the atmosphere through a 5.08 cm diameter tube as shown in Fig. P3.88. The end of the tube is 0.9 m below the tank bottom, and viscous effects are negligible. **(a)** Determine the volume flowrate from the tank. **(b)** Determine the maximum height, H, over which the water can be siphoned without cavitation occurring. Atmospheric pressure is 101.3 kPa, and the water vapor pressure is 1.8 kPa.



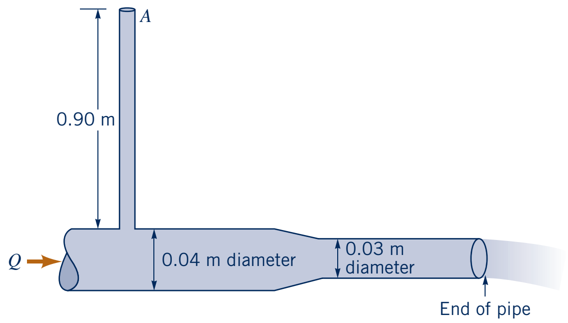
■ **Figure P3.88**

3.89 Determine the manometer reading, h, for the flow shown in Fig. P3.89.



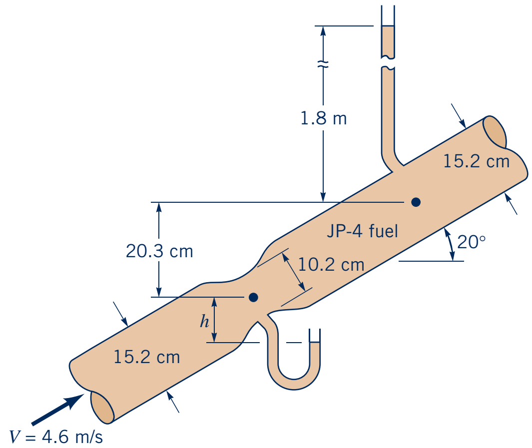
■ **Figure P3.89**

3.90 Water flows steadily from the pipe shown in Fig. P3.90 with negligible viscous effects. Determine the maximum flowrate if the water is not to flow from the open vertical tube at A.



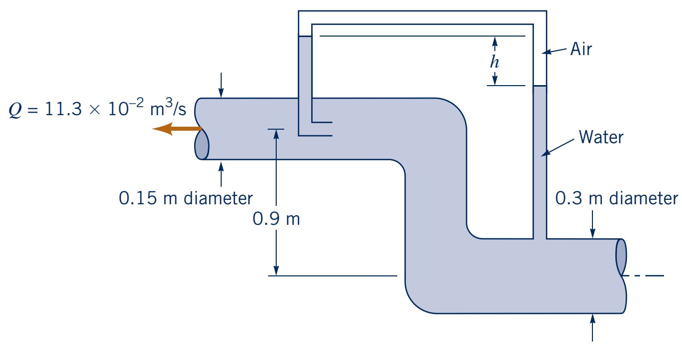
■ **Figure P3.90**

3.91 JP-4 fuel ($SG = 0.77$) flows through the Venturi meter shown in Fig. P3.91 with a velocity of 4.6 m/s in the 15.2 cm pipe. If viscous effects are negligible, determine the elevation, h, of the fuel in the open tube connected to the throat of the Venturi meter.



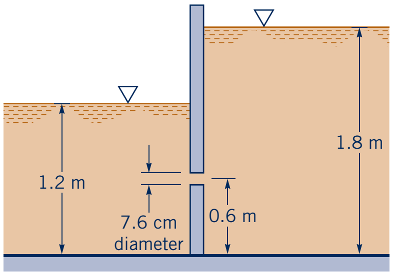
■ **Figure P3.91**

3.92 Water, considered an inviscid, incompressible fluid, flows steadily as shown in Fig. P3.92. Determine h.



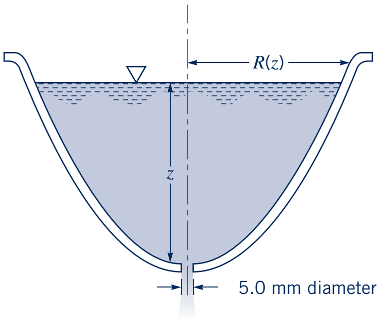
■ **Figure P3.92**

3.93 Determine the flowrate through the submerged orifice shown in Fig. P3.93 if the contraction coefficient is $C_c = 0.63$.



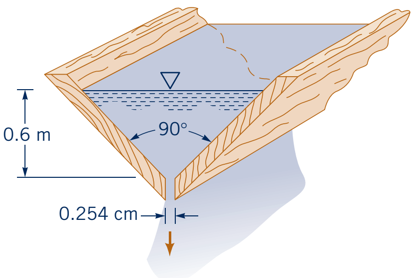
■ **Figure P3.93**

3.94 An ancient device for measuring time is shown in Fig. P3.94. The axisymmetric vessel is shaped so that the water level falls at a constant rate. Determine the shape of the vessel, $R = R(z)$, if the water level is to decrease at a rate of 0.10 m/h and the drain hole is 5.0 mm in diameter. The device is to operate for 12 h without needing refilling. Make a scale drawing of the shape of the vessel.



■ **Figure P3.94**

3.95 A long water trough of triangular cross section is formed from two planks as is shown in Fig. P3.95. A gap of 0.254 cm remains at the junction of the two planks. If the water depth initially was 0.6 m how long a time does it take for the water depth to reduce to 0.3 m?



■ **Figure P3.95**

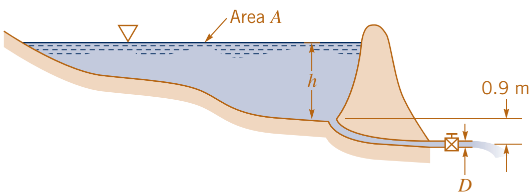
***3.96** A spherical tank of diameter D has a drain hole of diameter d at its bottom. A vent at the top of the tank maintains atmospheric pressure at the liquid surface within the tank. The flow is quasi-steady and inviscid and the tank is full of water initially. Determine the water depth as a function of time, $h = h(t)$, and plot graphs of $h(t)$ for tank diameters of 0.3, 1.5, 3.0, and 6.0 m if $d = 0.0254$ m.

†3.97 A small hole develops in the bottom of the stationary rowboat shown in Fig. P3.97. Estimate the amount of time it will take for the boat to sink. List all assumptions and show all calculations.

■ **Figure P3.97**

3.98 When the drain plug is pulled, water flows from a hole in the bottom of a large, open cylindrical tank. Show that if viscous effects are negligible and if the flow is assumed to be quasisteady, then it takes 3.41 times longer to empty the entire tank than it does to empty the first half of the tank. Explain why this is so.

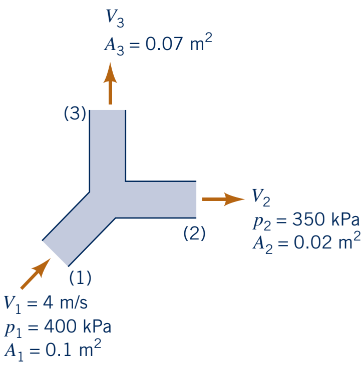
***3.99** The surface area, A, of the pond shown in Fig. P3.99 varies with the water depth, h, as shown in the table. At time $t = 0$ a valve is opened and the pond is allowed to drain through a pipe of diameter D. If viscous effects are negligible and quasisteady conditions are assumed, plot the water depth as a function of time from when the valve is opened ($t = 0$) until the pond is drained for pipe diameters of $D = 0.15$, 0.3, 0.45, 0.60, 0.75, and 0.9 m. Assume $h = 5.5$ m at $t = 0$.



■ **Figure P3.99**

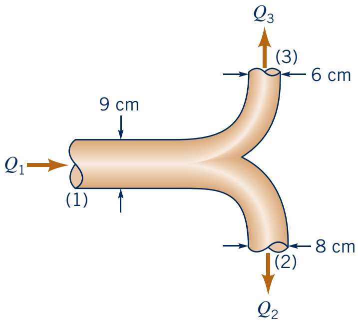
h **(m)**	**m²**
0	0
0.5	1200
1.0	2000
1.5	3200
2.0	3600
2.5	4500
3.0	6000
3.5	7300
4.0	9700
4.5	11,300

3.100 WILEY Water flows through a horizontal branching pipe as shown in Fig. P3.100. Determine the pressure at section (3).



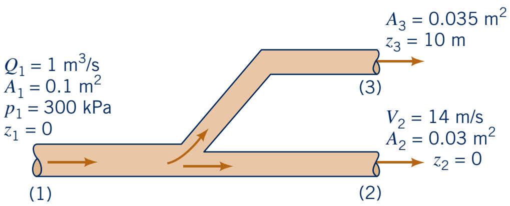
■ **Figure P3.100**

3.101 Water flows through the horizontal Y-fitting shown in Fig. P3.101. If the flowrate and pressure in pipe (1) are $Q_1 = 6.5 \times 10^{-2}$ m^3/s and $p_1 = 7.9$ kN/m^2, 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).



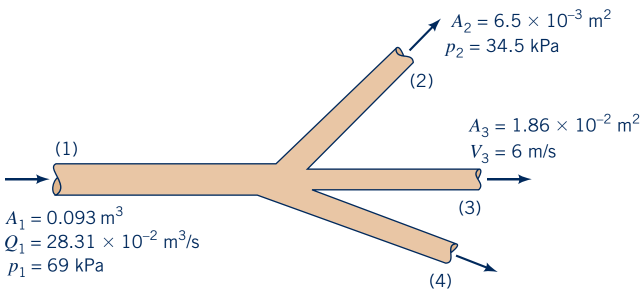
■ **Figure P3.101**

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).



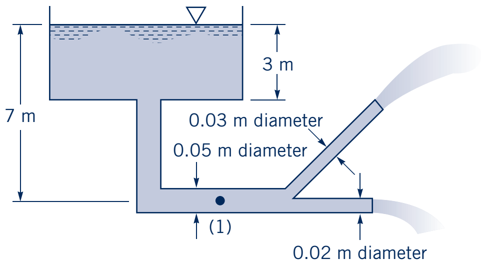
■ **Figure P3.102**

3.103 Water flows through the horizontal branching pipe shown in Fig. P3.103 at a rate of 0.3 m^3/s. If viscous effects are negligible, determine the water speed at section (2), the pressure at section (3), and the flowrate at section (4).



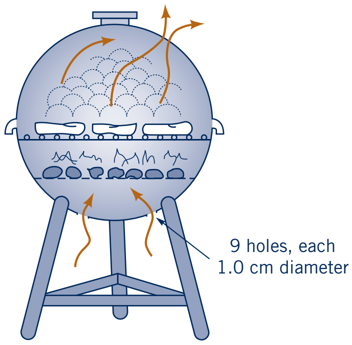
■ **Figure P3.103**

3.104 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).



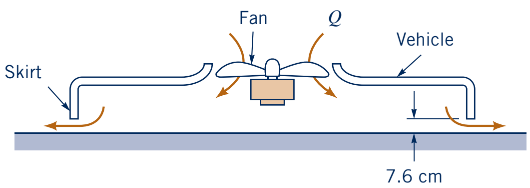
■ **Figure P3.104**

3.105 Air, assumed incompressible and inviscid, flows into the outdoor cooking grill through nine holes of 1.0 cm diameter as shown in Fig. P3.105. If a flowrate of 6.24×10^{-4} m^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 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 7.6 cm clearance between the lower end of the skirt and the ground (or water). Assume the vehicle weighs 44.4 kN and is essentially rectangular in shape, 9 by 20 m. 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 5.1 cm what flowrate would be needed? If the vehicle weight were reduced to 22.2 kN and the ground clearance maintained at 7.6 cm what flowrate would be needed?



■ **Figure P3.106**

3.107 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.

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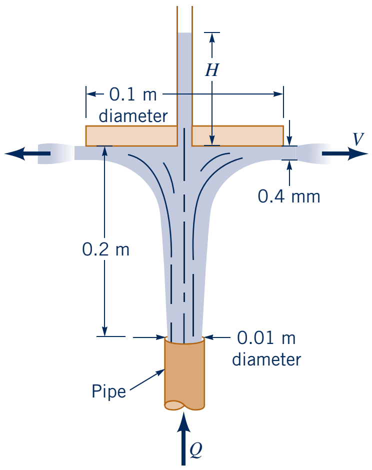
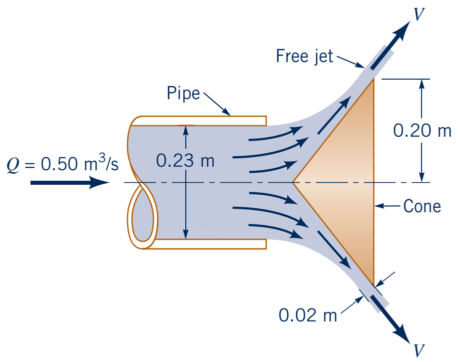


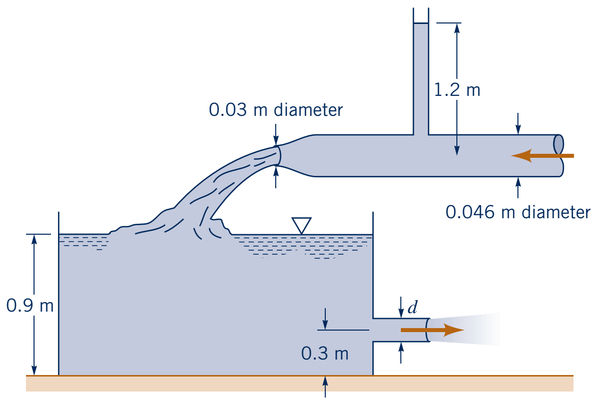
■ **Figure P3.107**

3.108 WILEY A conical plug is used to regulate the airflow from the pipe shown in Fig. P3.108. The air leaves the edge of the cone with a uniform thickness of 0.02 m. If viscous effects are negligible and the flowrate is 0.50 m^3/s, determine the pressure within the pipe.



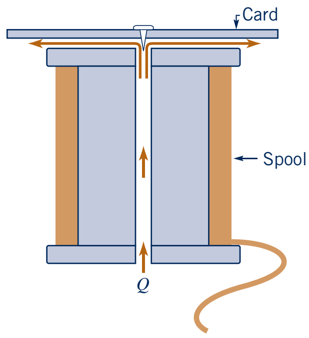
■ **Figure P3.108**

3.109 WILEY Water flows steadily from a nozzle into a large tank as shown in Fig. P3.109. The water then flows from the tank as a jet of diameter d. Determine the value of d if the water level in the tank remains constant. Viscous effects are negligible.



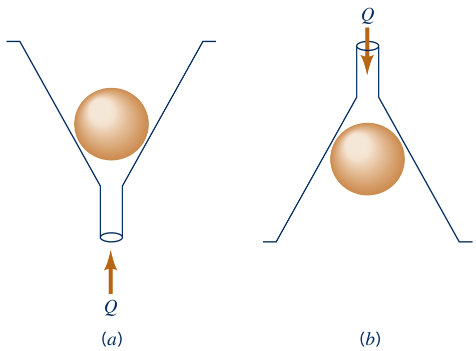
■ **Figure P3.109**

3.110 A small card is placed on top of a spool as shown in Fig. P3.110. It is not possible to blow the card off the spool by blowing air through the hole in the center of the spool. The harder one blows, the harder the card "sticks" to the spool. In fact by blowing hard enough it is possible to keep the card against the spool with the spool turned upside down. (*Note*: It may be necessary to use a thumb tack to prevent the card from sliding from the spool.) Explain this phenomenon.



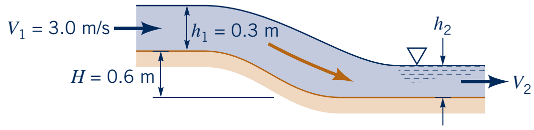
■ **Figure P3.110**

3.111 Observations show that it is not possible to blow the table tennis ball from the funnel shown in Fig. P3.111*a*. In fact, the ball can be kept in an inverted funnel, Fig P3.111*b*, by blowing through it. The harder one blows through the funnel, the harder the ball is held within the funnel. Explain this phenomenon.



■ **Figure P3.111**

3.112 Water flows down the sloping ramp shown in Fig. P3.112 with negligible viscous effects. The flow is uniform at sections (1) and (2). For the conditions given show that three solutions for the downstream depth, h_2, are obtained by use of the Bernoulli and continuity equations. However, show that only two of these solutions are realistic. Determine these values.



■ **Figure P3.112**

3.113 WILEY Water flows in a rectangular channel that is 2.0 m wide as shown in Fig. P3.113. The upstream depth is 70 mm. The water surface rises 40 mm as it passes over a portion where the channel bottom rises 10 mm. If viscous effects are negligible, what is the flowrate?

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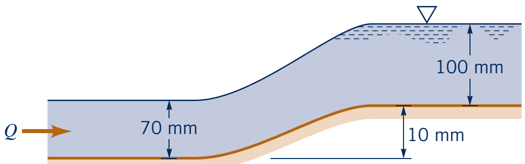


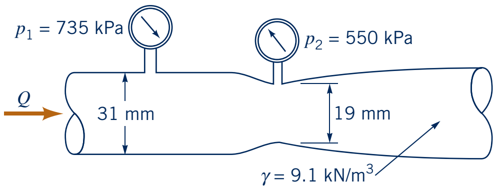
■ Figure P3.113

Section 3.6.3 Flowrate Measurement (also see Lab Problems 3.2LP and 3.4LP)

3.114 Obtain a photograph/image of a situation that involves some type of flowmeter. Print this photo and write a brief paragraph that describes the situation involved.

3.115 WILEY A Venturi meter with a minimum diameter of 7.6 cm is to be used to measure the flowrate of water through a 10.2 cm diameter pipe. Determine the pressure difference indicated by the pressure gage attached to the flowmeter if the flowrate is 1.4×10^{-2} m^3/s and viscous effects are negligible.

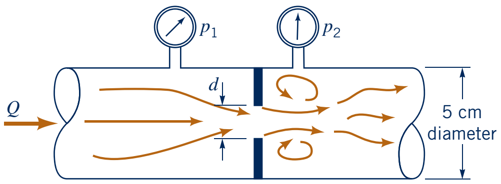
3.116 WILEY Determine the flowrate through the Venturi meter shown in Fig. P3.116 if ideal conditions exist.



■ Figure P3.116

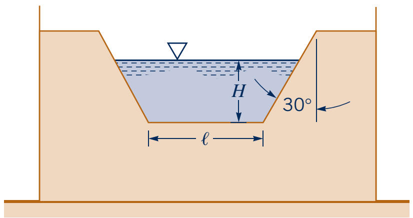
3.117 WILEY GO For what flowrate through the Venturi meter of Problem 3.116 will cavitation begin if $p_1 = 275$ kPa gage, atmospheric pressure is 101 kPa (abs), and the vapor pressure is 3.6 kPa (abs)?

3.118 What diameter orifice hole, d, is needed if under ideal conditions the flowrate through the orifice meter of Fig. P3.118 is to be 113 L/min of seawater with $p_1 - p_2 = 16.34$ kPa? The contraction coefficient is assumed to be 0.63.



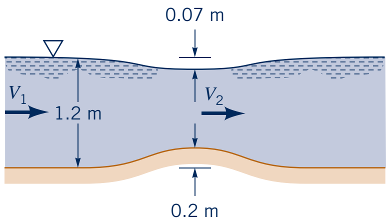
■ Figure P3.118

3.119 A weir (see **Video V10.13**) of trapezoidal cross section is used to measure the flowrate in a channel as shown in Fig. P3.119. If the flowrate is Q_0 when $H = \ell/2$, what flowrate is expected when $H = \ell$?



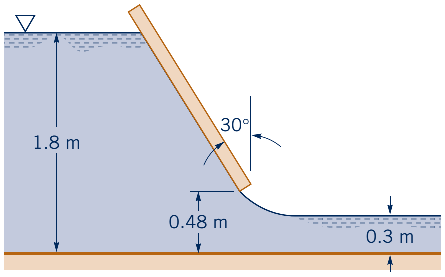
■ Figure P3.119

3.120 The flowrate in a water channel is sometimes determined by use of a device called a Venturi flume. As shown in Fig. P3.120, this device consists simply of a bump on the bottom of the channel. If the water surface dips a distance of 0.07 m for the conditions shown, what is the flowrate per width of the channel? Assume the velocity is uniform and viscous effects are negligible.



■ Figure P3.120

3.121 WILEY Water flows under the inclined sluice gate shown in Fig. P3.121. Determine the flowrate if the gate is 2.4 m wide.



■ Figure P3.121

Section 3.7 The Energy Line and the Hydraulic Grade Line

3.122 WILEY Water flows in a vertical pipe of 0.15 m diameter at a rate of 0.2 m^3/s and a pressure of 200 kPa at an elevation of 25 m. Determine the velocity head and pressure head at elevations of 20 and 55 m.

3.123 WILEY Draw the energy line and the hydraulic grade line for the flow of Problem 3.83.

3.124 Draw the energy line and hydraulic grade line for the flow shown in Problem 3.71.

Section 3.8 Restrictions on Use of the Bernoulli Equation

3.125 Obtain a photograph/image of a flow in which it would not be appropriate to use the Bernoulli equation. Print this photo and write a brief paragraph that describes the situation involved.

3.126 WILEY Listed below are typical flight speeds for two aircraft. For which of these conditions would it be reasonable to use the incompressible Bernoulli equation to study the aerodynamics associated with their flight? Explain.

	Flight speed, km/h	
Aircraft	**Cruise**	**Landing approach**
Boeing 787	913	214
F-22 fighter	1960	250

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3.127 A meteorologist uses a Pitot-static tube to measure the wind speed in a tornado. Based on the damage caused by the storm, the tornado is rated as EF5 on the Enhanced Fujita Scale. This means that the wind speed is estimated to be in the range of 261 to 318 mph. Is it reasonable to use the incompressible Pitot-tube equation (Eq. 3.16) to determine the actual wind speed, or must compressible effects be taken into account? Explain.

■ Lab Problems

3.1 LP This problem involves the pressure distribution between two parallel circular plates. 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.

3.2 LP This problem involves the calibration of a nozzle-type flowmeter. 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.

3.3 LP This problem involves the pressure distribution in a two-dimensional channel. 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.

3.4 LP This problem involves the determination of the flowrate under a sluice gate as a function of the water depth. 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

3.1 LL The concept of the use of a Pitot-static tube to measure the airspeed of an airplane is rather straightforward. However, the design and manufacture of reliable, accurate, inexpensive Pitot-static tube airspeed indicators is not necessarily simple. Obtain information about the design and construction of modern Pitot-static tubes. Summarize your findings in a brief report.

3.2 LL In recent years damage due to hurricanes has been significant, particularly in the southeastern United States. The low barometric pressure, high winds, and high tides generated by hurricanes can combine to cause considerable damage. According to some experts, in the coming years hurricane frequency may increase because of global warming. Obtain information about the fluid mechanics of hurricanes. Summarize your findings in a brief report.

3.3 LL Orifice, nozzle, or Venturi flowmeters have been used for a long time to predict accurately the flowrate in pipes. However, recently there have been several new concepts suggested or used for such flowrate measurements. Obtain information about new methods to obtain pipe flowrate information. Summarize your findings in a brief report.

3.4 LL Ultra-high-pressure, thin jets of liquids can be used to cut various materials ranging from leather to steel and beyond. Obtain information about new methods and techniques proposed for liquid jet cutting and investigate how they may alter various manufacturing processes. Summarize your findings in a brief report.

■ 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.

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