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PROBLEMS

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

WILEY GO Guided Online (GO) Problem, available in *WileyPLUS* at instructor's discretion.

Notes on Pipe Diameter for Chapter 10 Problems

When a pipe diameter is given using the label "NPS" or "nominal," find the dimensions using Table 10.1 on p. 363 of §10.2. Otherwise, assume the specified diameter is an inside diameter (ID).

Classifying Flow (§10.1)

10.1 WILEY PLUS Kerosene (20°C) flows at a rate of 0.02 m^3/s in a 17.7-cm-diameter pipe. Would you expect the flow to be laminar or turbulent? Calculate the entrance length.

10.2 WILEY PLUS A compressor draws 0.3 m^3/s of ambient air (20°C) in from the outside through a round duct that is 10 m long and 150 mm in diameter. Determine the entrance length and establish whether the flow is laminar or turbulent.

10.3 Design a lab demo for laminar flow. Specify the diameter and length for a tube that carries SAE 10W-30 oil at 38°C so that the system demonstrates laminar flow, and fully developed flow, with a discharge of $Q = 0.1$ L/s.

Darcy-Weisbach Equation (§10.3)

10.4 Using §10.3 and other resources, answer the following questions. Strive for depth, clarity, and accuracy while also combining sketches, words, and equations in ways that enhance the effectiveness of your communication.

a. What is pipe head loss? How is pipe head loss related to total head loss?

b. What is the friction factor f? How is f related to wall shear stress?

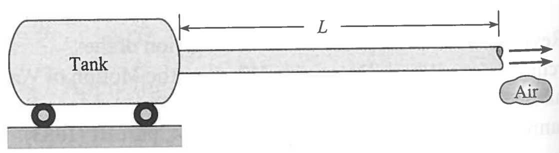
c. What assumptions need to be satisfied to apply the Darcy-Weisbach equation?

10.5 WILEY PLUS For each case that follows, apply the Darcy-Weisbach equation from Eq. (10.12) in §10.3 to calculate the head loss in a pipe. Apply the grid method to carry and cancel units.

a. Water flows at a rate of 75 lpm and a mean velocity of 55 m/min in a pipe of length 60 m. For a resistance coefficient of $f = 0.02$, find the head loss in meters.

b. The head loss in a section of PVC pipe is 0.8 m, the resistance coefficient is $f = 0.012$, the length is 15 m, and the flow rate is 0.028 m^3/s. Find the pipe diameter in meters.

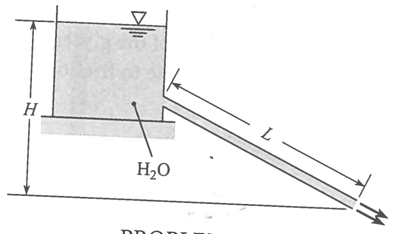
10.6 WILEY PLUS As shown, air (20°C) is flowing from a large tank, through a horizontal pipe, and then discharging to ambient. The pipe length is $L = 50$ m, and the pipe is schedule 40 PVC with a nominal diameter of 25 mm. The mean velocity in the pipe is 10 m/s, and $f = 0.015$. Determine the pressure (in Pa) that needs to be maintained in the tank.



PROBLEM 10.6

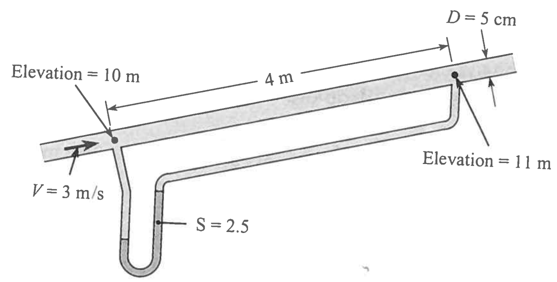
10.7 WILEY PLUS Water (15°C) flows through a garden hose (ID = 22 mm) with a mean velocity of 2 m/s. Find the pressure drop for a section of hose that is 20 meters long and situated horizontally. Assume that $f = 0.012$.

10.8 WILEY GO As shown, water (15°C) is flowing from a tank through a tube and then discharging to ambient. The tube has an ID of 8 mm and a length of $L = 6$ m, and the resistance coefficient is $f = 0.015$. The water level is $H = 3$ m. Find the exit velocity in m/s. Find the discharge in L/s. Sketch the HGL and the EGL. Assume that the only head loss occurs in the tube.



PROBLEM 10.8

10.9 WILEY PLUS Water flows in the pipe shown, and the manometer deflects 90 cm. What is f for the pipe if $V = 3$ m/s?



PROBLEM 10.9

Laminar Flow in Pipes (§10.5)

10.10 Using §10.5 and other resources, answer the questions that follow. Strive for depth, clarity, and accuracy while also combining sketches, words, and equations in ways that enhance the effectiveness of your communication.

a. What are the main characteristics of laminar flow?

b. What is the meaning of each variable that appears in Eq. (10.27) in §10.5?

c. In Eq. (10.33) of §10.5, what is the meaning of h_f?

10.11 WILEY GO A fluid ($\mu = 10^{-2}$ N · s/m²; $\rho = 800$ kg/m³) flows with a mean velocity of 4 cm/s in a 10 cm smooth pipe.

a. What is the value of Reynolds number?

b. What is the magnitude of the maximum velocity in the pipe?

c. What is the magnitude of the friction factor f?

d. What is the shear stress at the wall?

e. What is the shear stress at a radial distance of 25 mm from the center of the pipe?

10.12 WILEY PLUS Water (15°C) flows in a horizontal schedule 40 pipe that has a nominal diameter of 15 mm. The Reynolds number is Re = 1000. Work in SI units.

a. What is mass flow rate?

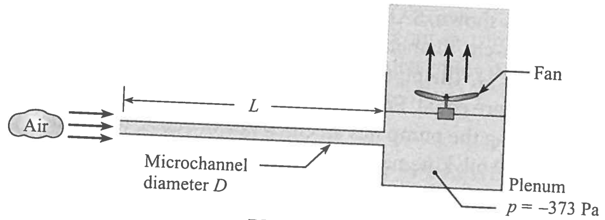
b. What is the magnitude of the friction factor f?

c. What is the head loss per meter of pipe length?

d. What is the pressure drop per meter of pipe length?

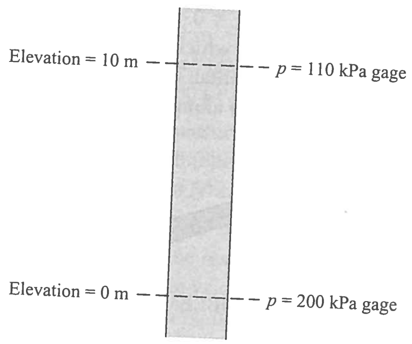
10.13 Flow of a liquid in a smooth 2.5 cm pipe yields a head loss of 2 m per meter of pipe length when the mean velocity is 0.5 m/s. Calculate f and the Reynolds number. Prove that doubling the flow rate will double the head loss. Assume fully developed flow.

10.14 WILEY PLUS As shown, a round tube of diameter 0.5 mm and length 750 mm is connected to plenum. A fan produces a negative gage pressure of −373 Pa in the plenum and draws air (20°C) into the microchannel. What is the mean velocity of air in the microchannel? Assume that the only head loss is in the tube.



PROBLEM 10.14

10.15 Liquid ($\gamma = 10$ kN/m³) is flowing in a pipe at a steady rate, but the direction of flow is unknown. Is the liquid moving upward or moving downward in the pipe? If the pipe diameter is 8 mm and the liquid viscosity is 3.0×10^{-3} N · s/m², what is the magnitude of the mean velocity in the pipe?

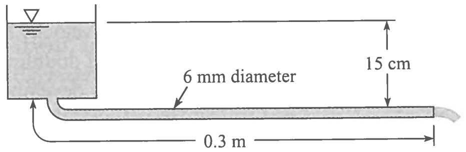


PROBLEM 10.15

10.16 WILEY PLUS Oil (S = 0.97, $\mu = 0.479$ Pa · s) is pumped through a nominal 25 mm, schedule 80 pipe at the rate of 1×10^{-4} m³/s. What is the head loss per 30 m of level pipe?

10.17 WILEY PLUS A liquid ($\rho = 1000$ kg/m³; $\mu = 10^{-1}$ N · s/2 m²; $\nu = 10^{-4}$ m²/s) flows uniformly with a mean velocity of 1.5 m/s in a pipe with a diameter of 100 mm. Show that the flow is laminar. Also, find the friction factor f and the head loss per meter of pipe length.

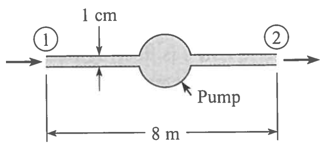
10.18 Kerosene (S = 0.80 and $T = 20°C$) flows from the tank shown and through the 6 mm–diameter (ID) tube. Determine the mean velocity in the tube and the discharge. Assume the only head loss is in the tube.



PROBLEM 10.18

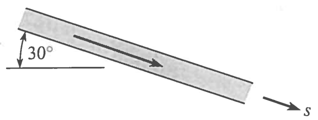
10.19 Oil (S = 0.94; $\mu = 0.048$ N · s/m^2) is pumped through a horizontal 5 cm pipe. Mean velocity is 0.5 m/s. What is the pressure drop per 10 m of pipe?

10.20 As shown, SAE 10W-30 oil is pumped through an 8 m length of 1-cm-diameter drawn tubing at a discharge of 7.85×10^{-4} m^3/s. The pipe is horizontal, and the pressures at points 1 and 2 are equal. Find the power necessary to operate the pump, assuming the pump has an efficiency of 100%. Properties of SAE 10W-30 oil: kinematic viscosity = 7.6×10^{-5} m^2/s; specific weight = 8630 N/m^3.



PROBLEM 10.20

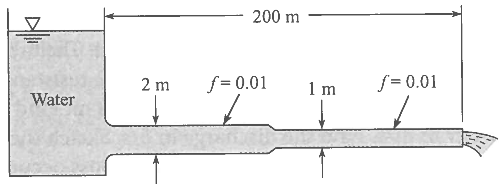
10.21 Oil (S = 0.80; $\mu = 0.479$ Pa · s; $\nu = 0.00053$ m^2/s) flows downward in the pipe, which is 0.03 m in diameter and has a slope of 30° with the horizontal. Mean velocity is 1 m/s. What is the pressure gradient (dp/ds) along the pipe?



PROBLEM 10.21

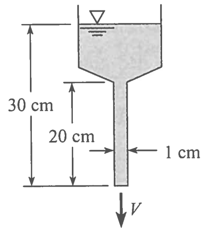
10.22 In the pipe system shown, for a given discharge, the ratio of the head loss in a given length of the 1 m pipe to the head loss in the same length of the 2 m pipe is (a) 2, (b) 4, (c) 16, or (d) 32.

10.23 Glycerine ($T = 20°C$) flows in a pipe with a 150-mm diameter at a mean velocity of 0.45 m/s. Is the flow laminar or turbulent? Plot the velocity distribution across the flow section, in 12-mm increments of radius.



PROBLEM 10.22

10.24 Glycerine ($T = 20°C$) flows through a funnel as shown. Calculate the mean velocity of the glycerine exiting the tube. Assume the only head loss is due to friction in the tube.



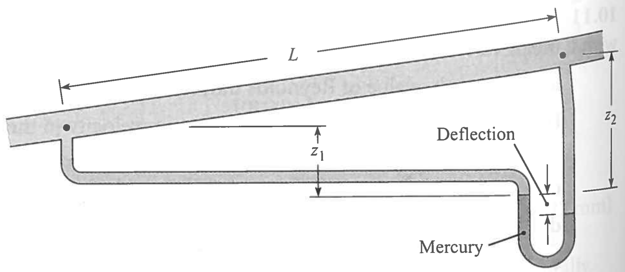
PROBLEM 10.24

10.25 What nominal size of steel pipe should be used to carry 0.006 m^3/s of castor oil at 32°C a distance of 0.8 km with an allowable pressure drop of 70 kPa ($\mu = 4$ Pa · s)? Assume S = 0.85.

10.26 Velocity measurements are made in a 30-cm pipe. The velocity at the center is found to be 1.5 m/s, and the velocity distribution is observed to be parabolic. If the pressure drop is found to be 1.9 kPa per 100 m of pipe, what is the kinematic viscosity ν of the fluid? Assume that the fluid's specific gravity is 0.80.

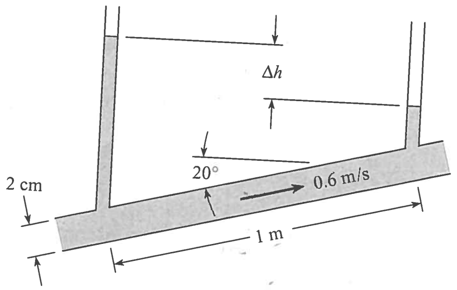
10.27 The velocity of oil (S = 0.8) through the 5-cm smooth pipe is 1.2 m/s. Here $L = 12$ m, $z_1 = 1$ m, $z_2 = 2$ m, and the manometer deflection is 10 cm. Determine the flow direction, the resistance coefficient f, whether the flow is laminar or turbulent, and the viscosity of the oil.

10.28 The velocity of oil (S = 0.8) through the 50-mm smooth pipe is 1.5 m/s. Here $L = 9$ m, $z_1 = 0.6$ m, $z_2 = 1.2$ m, and the manometer deflection is 100 mm. Determine the flow direction, the resistance coefficient f, whether the flow is laminar or turbulent, and the viscosity of the oil.



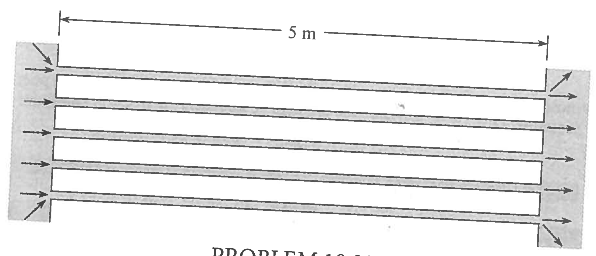
PROBLEMS 10.27, 10.28

10.29 Glycerine at 20°C flows at 0.6 m/s in the 2-cm commercial steel pipe. Two piezometers are used as shown to measure the piezometric head. The distance along the pipe between the standpipes is 1 m. The inclination of the pipe is 20°. What is the height difference Δh between the glycerine in the two standpipes?



PROBLEM 10.29

10.30 Water is pumped through a heat exchanger consisting of tubes 6 mm in diameter and 6 m long. The velocity in each tube is 12 cm/s. The water temperature increases from 20°C at the entrance to 30°C at the exit. Calculate the pressure difference across the heat exchanger, neglecting entrance losses but accounting for the effect of temperature change by using properties at average temperatures.



PROBLEM 10.30

Turbulent Flow in Pipes (§10.6)

10.31 Use Figure 10.14, Table 10.3, and Table 10.4 (in §10.6) to assess the following statements as True or False:

a. If k_s/D is 0.05 or larger, and the flow is turbulent, the value of f is not dependent on Re_D.

b. For smooth pipes and turbulent flow, f depends on k_s/D and not Re_D.

c. For laminar flow, f is always given by $f = 64/Re_D$.

d. If $Re_D = 2 \times 10^7$ and $k_s/D = 0.00005$, then $f = 0.012$.

e. If $Re_D = 1000$ and the pipe is smooth, $f = 0.04$.

f. The sand roughness height k_s for wrought iron is 0.002 mm.

10.32 Water (21°C) flows through a nominal 100-mm, schedule 40, PVC pipe at the rate of 0.03 m^3/s. What is the resistance coefficient f? Use the Swamee-Jain Eq. (10.39) in §10.6.

10.33 Water at 20°C flows through a 2-cm ID smooth brass tube at a rate of 0.003 m^3/s. What is f for this flow? Use the Swamee-Jain Eq. (10.39) in §10.6.

10.34 Water (10°C) flows through a 25-cm smooth pipe at a rate of 0.05 m^3/s. What is the resistance coefficient f?

10.35 What is f for the flow of water at 10°C through a 10-cm cast-iron pipe with a mean velocity of 4 m/s?

10.36 A fluid ($\mu = 10^{-2}$ N · s/m^2; $\rho = 800$ kg/m^3) flows with a mean velocity of 500 mm/s in a 100-mm-diameter smooth pipe. Answer the following questions relating to the given flow conditions.

a. What is the magnitude of the maximum velocity in the pipe?

b. What is the magnitude of the resistance coefficient f?

c. What is the shear velocity?

d. What is the shear stress at a radial distance of 25 mm from the center of the pipe?

e. If the discharge is doubled, will the head loss per length of pipe also be doubled?

10.37 Water (20°C) flows in a 16-cm cast-iron pipe at a rate of 0.1 m^3/s. For these conditions, determine or estimate the following:

a. Reynolds number

b. Friction factor f (use Swamee-Jain Eq. (10.39) in §10.6.)

c. Shear stress at the wall, τ_0

10.38 In a 100-mm uncoated cast-iron pipe, 0.0006 m^3/s of water flows at 15°C. Determine f from Fig. 10.14.

10.39 Determine the head loss in 270 m of a concrete pipe with a 150-mm diameter ($k_s = 0.06$ mm) carrying 0.085 m^3/s of fluid. The properties of the fluid are $\nu = 3 \times 10^{-4}$m^2/s and $\rho = 773$ kg/m^3.

10.40 Points A and B are 1.5 km apart along a 15-cm new steel pipe ($k_s = 4.6 \times 10^{-5}$ m). Point B is 20 m higher than A. With a flow from A to B of 0.03 m^3/s of crude oil (S = 0.82) at 10°C ($\mu = 10^{-2}$ N · s/m^2), what pressure must be maintained at A if the pressure at B is to be 300 kPa?

10.41 A pipe can be used to measure the viscosity of a fluid. A liquid flows in a 1.5-cm smooth pipe 1 m long with an average velocity of 4 m/s. A head loss of 50 cm is measured. Estimate the kinematic viscosity.

10.42 For a 40-cm pipe, the resistance coefficient f was found to be 0.06 when the mean velocity was 3 m/s and the kinematic viscosity was 10^{-5} m^2/s. If the velocity were doubled, would you expect the head loss per meter of length of pipe to double, triple, or quadruple?

10.43 Water (10°C) flows with a speed of 1.5 m/s through a horizontal run of PVC pipe. The length of the pipe is 30 m, and the pipe is schedule 40 with a nominal diameter of 65 mm. Calculate (a) the pressure drop in kPa, (b) the head loss in meters, and (c) the power in watts needed to overcome the head loss.

10.44 Water (10°C) flows with a speed of 2 m/s through a horizontal run of PVC pipe. The length of the pipe is 50 m, and the pipe is schedule 40 with a nominal diameter of 65 mm. Calculate (a) the pressure drop in kilopascals, (b) the head loss in meters, and (c) the power in watts needed to overcome the head loss.

10.45 Air flows in a 3-cm smooth tube at a rate of 0.015 m^3/s. If $T = 20°C$ and $p = 110$ kPa absolute, what is the pressure drop per meter of length of tube?

10.46 Points *A* and *B* are 4.8 km apart along a 600-mm new cast-iron pipe carrying water ($T = 10°C$). Point *A* is 9 m higher than *B*. The pressure at *B* is 140 kPa greater than that at *A*. Determine the direction and rate of flow.

10.47 Air flows in a 25-mm smooth tube at a rate of 1.42×10^{-2} m^3/s. If $T = 25°C$ and $p = 103.4$ kPa, what is the pressure drop per meter of length of tube?

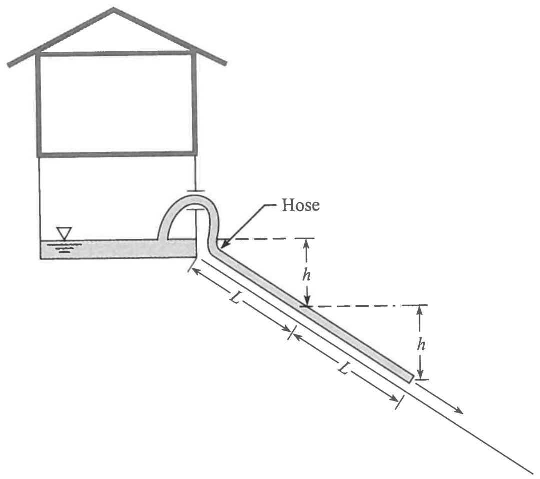
10.48 Water is pumped through a vertical 10-cm new steel pipe to an elevated tank on the roof of a building. The pressure on the discharge side of the pump is 1.6 MPa. What pressure can be expected at a point in the pipe 110 m above the pump when the flow is 0.02 m^3/s? Assume $T = 20°C$.

10.49 The house located on a hill as shown is flooded by a broken waterline. The frantic owners siphon water out of the basement window and down the hill in the backyard, with one hose, of length *L*, and thus an elevation difference of *h* to drive the siphon. Water drains from the siphon, but too slowly for the desperate home owners. They reason that with a larger head difference, they can generate more flow. So they get another hose, same length as the first, and connect the 2 hoses for total length 2*L*. The backyard has a constant slope, so that a hose length of 2*L* correlates to a head difference of 2*h*.

a. Assume no head loss, and calculate whether the flow rate doubles when the hose length is doubled from Case 1 (length *L* and height *h*) to Case 2 (length 2*L* and height 2*h*).

b. Assume $h_L = 0.025(L/D)(V^2/2g)$, and calculate the flow rate for Cases 1 and 2, where $D = 0.025$ m, $L = 15$ m, and $h = 6$ m. How much of an improvement in flow rate is accomplished in Case 2 as compared to Case 1?

c. Both the husband and wife of this couple took fluid mechanics in college. They review with new appreciation the energy equation and the form of the head loss term and realize that they should use a larger diameter hose. Calculate the flow rate for Case 3, where $L = 15$ m, $h = 6$ m, and $D = 50$ mm. Use the same expression for h_L as in part (b). How much of an improvement in flow rate is accomplished in Case 3 as compared to Case 1 in part (b)?



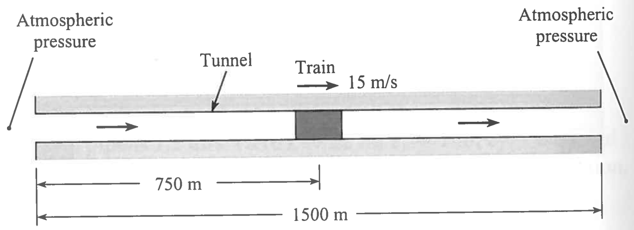
PROBLEM 10.49

10.50 A train travels through a tunnel as shown. The train and tunnel are circular in cross section. Clearance is small, causing all air (15°C) to be pushed from the front of the train and discharged from the tunnel. The tunnel is 3 m in diameter and is concrete. The train speed is 15 m/s. Assume the concrete is very rough ($k_s = 0.015$ m).

a. Determine the change in pressure between the front and rear of the train that is due to *pipe friction* effects.

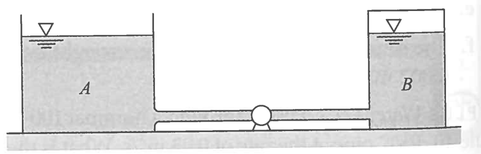
b. Sketch the energy and hydraulic grade lines for the train position shown.

c. What power is required to produce the air flow in the tunnel?



PROBLEM 10.50

10.51 Water (15°C) is pumped from a reservoir to a large, pressurized tank as shown. The steel pipe is 100 mm in diameter and 90 m long. The discharge is 0.03 m^3/s. The initial water levels in the tanks are the same, but the pressure in tank *B* is 70 kPa gage, and tank *A* is open to the atmosphere. The pump efficiency is 90%. Find the power necessary to operate the pump for the given conditions.



PROBLEM 10.51

Solving Turbulent Flow Problems (§10.7)

10.52 Using the information at the beginning of §10.7, classify each problem given below as case 1, case 2, or case 3. For each of your choices, state your rationale.

a. Problem 10.51

b. Problem 10.54

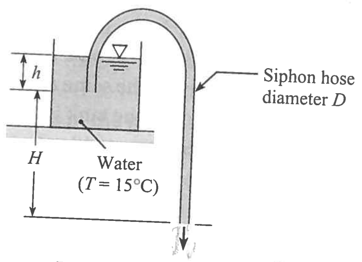
c. Problem 10.57

10.53 A plastic siphon hose with $D = 1.2$ cm and $L = 5.5$ m is used to drain water (15°C) out a tank. Calculate the velocity in the tube for the two situations given below. Use $H = 3$ m and $h = 1$ m.

a. Assume the Bernoulli equation applies (neglect all head loss).

b. Assume the component head loss is zero, and the pipe head loss is nonzero.

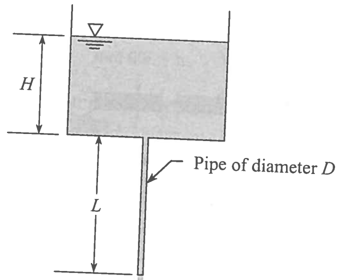
10.54 A plastic siphon hose of length 7 m is used to drain water (15°C) out of a tank. For a flow rate of 1.5 L/s, what hose diameter is needed? Use $H = 5$ m and $h = 0.5$ m. Assume all head loss occurs in the tube.



PROBLEMS 10.53, 10.54

10.55 As shown, water (21°C) is draining from a tank through a galvanized iron pipe. The pipe length is $L = 3$ m, the tank depth is $H = 1.2$ m, and the pipe is 25-mm DN schedule 40. Calculate the velocity in the pipe and the flow rate. Neglect component head loss.

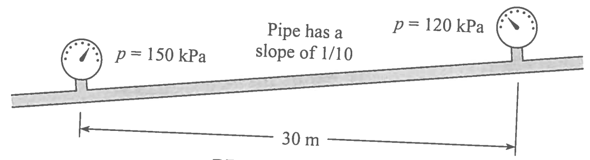
10.56 As shown, water (15°C) is draining from a tank through a galvanized iron pipe. The pipe length is $L = 2$ m, the tank depth is $H = 1$ m, and the pipe is a 15-mm DN schedule 40. Calculate the velocity in the pipe. Neglect component head loss.



PROBLEMS 10.55, 10.56

10.57 Air (40°C, 1 atm) will be transported in a straight horizontal copper tube over a distance of 150 m at a rate of 0.1 m^3/s. If the pressure drop in the tube should not exceed 6 in H_2O, what is the minimum pipe diameter?

10.58 A fluid with $\nu = 10^{-6}$ m^2/s and $\rho = 800$ kg/m^3 flows through the 8-cm galvanized iron pipe. Estimate the flow rate for the conditions shown in the figure.



PROBLEM 10.58

10.59 Determine the diameter of commercial steel pipe required to convey 8.5 m^3/s of water at 15°C with a head loss of 0.3 m per 300 m of pipe. Assume pipes are available in the multiple on 50 mm sizes when the diameters are expressed in millimeter (that is, 250 mm, 300 mm etc.).

10.60 A pipeline is to be designed to carry crude oil ($S = 0.93$, $\nu = 10^{-5}$ m^2/s) with a discharge of 0.10 m^3/s and a head loss per kilometer of 50 m. What diameter of steel pipe is needed? What power output from a pump is required to maintain this flow? Available pipe diameters are 20, 22, and 24 cm.

Combined Head Loss in Systems (§10.8)

10.61 Use Table 10.5 (on p. 381 in §10.8) to select loss coefficients, *K*, for the following transitions and fittings.

a. A threaded pipe 90° elbow

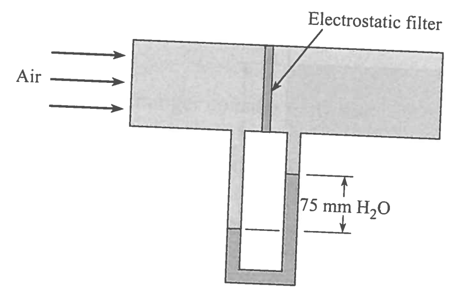
b. A 90° smooth bend with $r/d = 2$

c. A pipe entrance with r/d of 0.3

d. An abrupt contraction, with $\theta = 180°$, and $D_2/D_1 = 0.60$

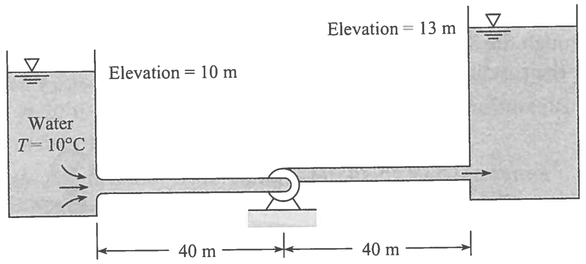
e. A gate valve, wide open

10.62 The sketch shows a test of an electrostatic air filter. The pressure drop for the filter is 75 mm of water when the airspeed is 10 m/s. What is the minor loss coefficient for the filter? Assume air properties at 20°C.



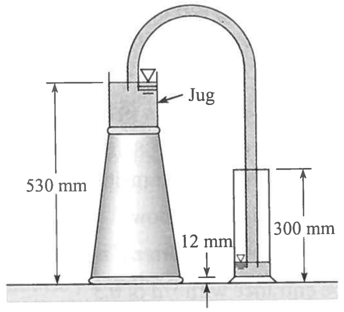
PROBLEM 10.62

10.63 WILEY PLUS If the flow of 0.10 m^3/s of water is to be maintained in the system shown, what power must be added to the water by the pump? The pipe is made of steel and is 15 cm in diameter.



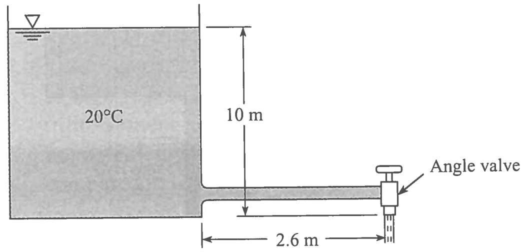
PROBLEM 10.63

10.64 Water will be siphoned through a 5 mm-diameter, 1.2-m-long Tygon tube from a jug on an upside-down wastebasket into a graduated cylinder as shown. The initial level of the water in the jug is 530 mm above the tabletop. The graduated cylinder is a 500 mL cylinder, and the water surface in the cylinder is 300 mm above the tabletop when the cylinder is full. The bottom of the cylinder is 12 mm above the table. The inside diameter of the jug is 180 mm. Calculate the time it will take to fill the cylinder from an initial depth of 50 mm of water in the cylinder.



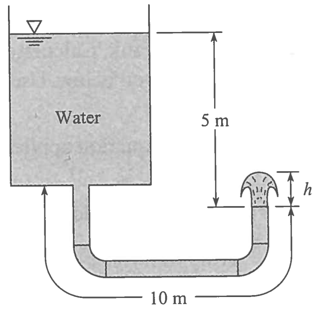
PROBLEM 10.64

10.65 Water flows from a tank through a 2.6-m length of galvanized iron pipe 26 mm in diameter. At the end of the pipe is an angle valve that is wide open. The tank is 2 m in diameter. Calculate the time required for the level in the tank to change from 10 m to 2 m. *Hint:* Develop an equation for dh/dt where h is the level and t if time. Then solve this equation numerically.



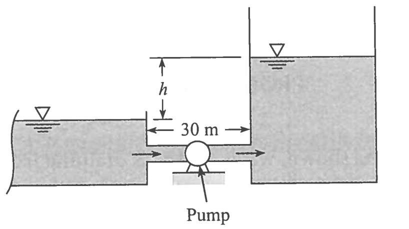
PROBLEM 10.65

10.66 WILEY PLUS A tank and piping system is shown. The galvanized pipe diameter is 1.5 cm, and the total length of pipe is 10 m. The two 90° elbows are threaded fittings. The vertical distance from the water surface to the pipe outlet is 5 m. The velocity of the water in the tank is negligible. Find (a) the exit velocity of the water and (b) the height (h) the water jet would rise on exiting the pipe. The water temperature is 20°C.



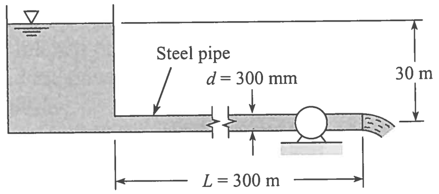
PROBLEM 10.66

10.67 A pump is used to fill a tank from a reservoir as shown. The head provided by the pump is given by $h_p = h_0(1 - (Q^2/Q_{max}^2))$ where h_0 is 50 meters, Q is the discharge through the pump, and Q_{max} is 2 m^3/s. Assume $f = 0.018$ and the pipe diameter is 90 cm. Initially the water level in the tank is the same as the level in the reservoir. The cross-sectional area of the tank is 100 m^2. How long will it take to fill the tank to a height, h, of 40 m?



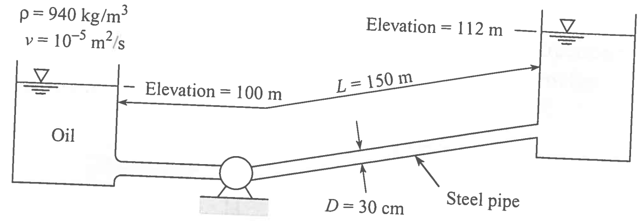
PROBLEM 10.67

10.68 WILEY GO A water turbine is connected to a reservoir as shown. The flow rate in this system is 0.14 m^3/s. What power can be delivered by the turbine if its efficiency is 80%? Assume a temperature of 21°C.



PROBLEM 10.68

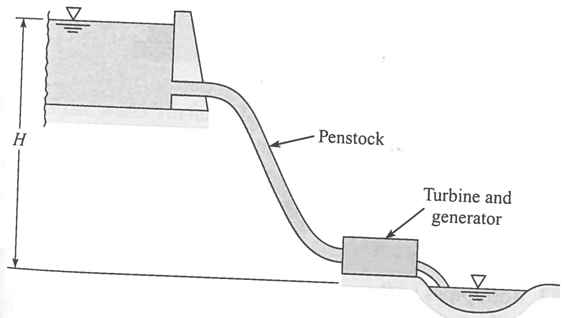
10.69 WILEY PLUS What power must the pump supply to the system to pump the oil from the lower reservoir to the upper reservoir at a rate of 0.20 m^3/s? Sketch the HGL and the EGL for the system.



PROBLEM 10.69

10.70 WILEY GO A cast-iron pipe 300 mm in diameter and 60 m long joins two water (15°C) reservoirs. The upper reservoir has a water-surface elevation of 45 m, and the lower on has a water-surface elevation of 12 m. The pipe exits from the side of the upper reservoir at an elevation of 36 m and enters the lower reservoir at an elevation of 9 m. There are two wide-open gate valves in the pipe. (a) List all sources of h_L and the quantitative factors associated with each. (b) Draw the EGL and the HGL for the system, and (c) determine the discharge in the pipe.

10.71 WILEY GO An engineer is making an estimate of hydroelectric power for a home owner. This owner has a small stream ($Q = 0.06$ m^3/s, $T = 5°C$) that is located at an elevation $H = 10$ m above the owner's residence. The owner is proposing to divert the stream and operate a water turbine connected to an electric generator to supply electrical power to the residence. The maximum acceptable head loss in the penstock (a penstock is a conduit that supplies a turbine) is 0.9 m. The penstock has a length of 26 m. If the penstock is going to be fabricated from commercial-grade, plastic pipe, find the minimum diameter that can be used. Neglect component head losses. Assume that pipes are available in following sizes—that is, like 50 mm, 100 mm, 150 mm, etc.

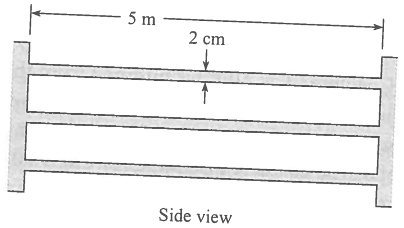


PROBLEM 10.71

10.72 The water-surface elevation in a reservoir is 45 m. A straight pipe 30 m long and 150 mm in diameter conveys water from the reservoir to an open drain. The pipe entrance (it is abrupt) is at elevation 30 m, and the pipe outlet is at elevation 18 m. At the outlet the water discharges freely into the air. The water temperature is 10°C. If the pipe is asphalted cast iron, what will be the discharge rate in the pipe? Consider all head losses. Also draw the HGL and the EGL for this system.

10.73 WILEY PLUS A heat exchanger is being designed as a component of a geothermal power system in which heat is transferred from the geothermal brine to a "clean" fluid in a closed-loop power cycle. The heat exchanger, a shell-and-tube type, consists of 100 galvanized-iron tubes 2 cm in diameter and 5 m long, as shown. The temperature of the fluid is 200°C, the density is 860 kg/m^3, and the viscosity is 1.35×10^{-4} N · s/m^2. The total mass flow rate through the exchanger is 50 kg/s.

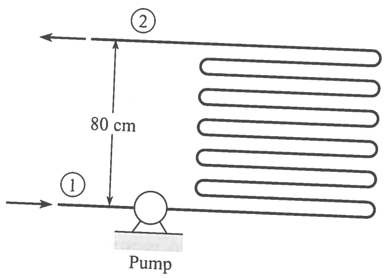
a. Calculate the power required to operate the heat exchanger, neglecting entrance and outlet losses.
b. After continued use, 2 mm of scale develops on the inside surfaces of the tubes. This scale has an equivalent roughness of 0.5 mm. Calculate the power required under these conditions.



Side view

PROBLEM 10.73

10.74 The heat exchanger shown consists of 10 m of drawn tubing 2 cm in diameter with 19 return bends. The flow rate is 3×10^{-4} m^3/s. Water enters at 20°C and exits at 80°C. The elevation difference between the entrance and the exit is 0.8 m. Calculate the pump power required to operate the heat exchanger if the pressure at 1 equals the pressure at 2. Use the viscosity corresponding to the average temperature in the heat exchanger.



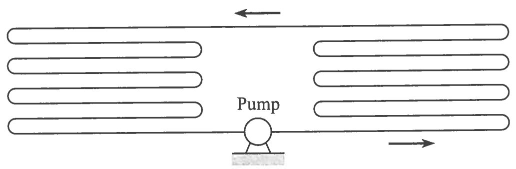
PROBLEM 10.74

10.75 WILEY PLUS A heat exchanger consists of a closed system with a series of parallel tubes connected by 180° elbows as shown in the figure. There are a total of 14 return elbows. The pipe diameter is 2 cm, and the total pipe length is 10 m. The head loss coefficient for each return elbow is 2.2. The tube is copper. Water with an average temperature of 40°C flows through the system with a mean velocity of 8 m/s. Find the power required to operate the pump if the pump is 85% efficient.

10.76 A heat exchanger consists of 15 m of copper tubing with an internal diameter of 15 mm. There are 14 return elbows in the system with a loss coefficient of 2.2 for each elbow. The pump in the system has a pump curve given by

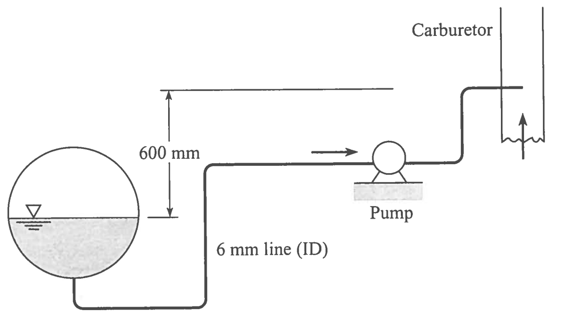
$$h_p = h_{p0}\left[1 - \left(\frac{Q}{Q_{max}}\right)^3\right]$$

where h_{p0} is head provided by the pump at zero discharge and Q_{max} is 10^{-3} m^3/s. Water at 40°C flows through the system. Find the system operating point for values of h_{p0} of 2 m, 10 m, and 20 m.



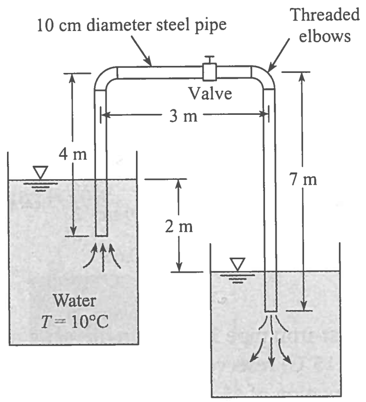
PROBLEMS 10.75, 10.76

10.77 Gasoline (T = 10°C) is pumped from the gas tank of an automobile to the carburetor through a 6-mm fuel line of drawn tubing 3 m long. The line has five 90° smooth bends with an r/d of 6. The gasoline discharges through a 0.75-mm jet in the carburetor to a pressure of 96.5 kPa abs. The pressure in the tank is 101.3 kPa abs. The pump is 80% efficient. What power must be supplied to the pump if the automobile is consuming fuel at the rate of 0.45 lpm? Obtain gasoline properties from Figs. A.2 and A.3.



PROBLEM 10.77

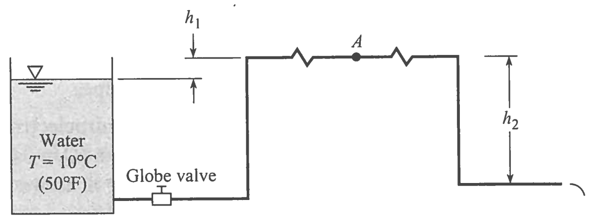
10.78 Find the loss coefficient K_v of the partially closed valve that is required to reduce the discharge to 50% of the flow with the valve wide open as shown.



PROBLEM 10.78

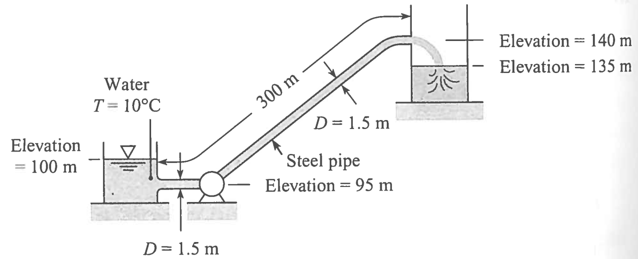
10.79 The pressure at a water main is 350 kPa gage. What size of pipe is needed to carry water from the main at a rate of 0.025 m^3/s to a factory that is 160 m from the main? Assume that galvanized-steel pipe is to be used and that the pressure required at the factory is 70 kPa gage at a point 8 m above the main connection.

10.80 The 12-cm galvanized-steel pipe shown is 800 m long and discharges water into the atmosphere. The pipeline has an open globe valve and four threaded elbows; h_1 = 3 m and h_2 = 15 m. What is the discharge, and what is the pressure at A, the midpoint of the line?



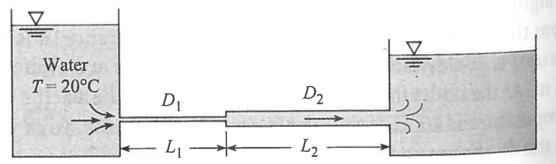
PROBLEM 10.80

10.81 Water is pumped at a rate of 25 m^3/s from the reservoir and out through the pipe, which has a diameter of 1.50 m. What power must be supplied to the water to effect this discharge?



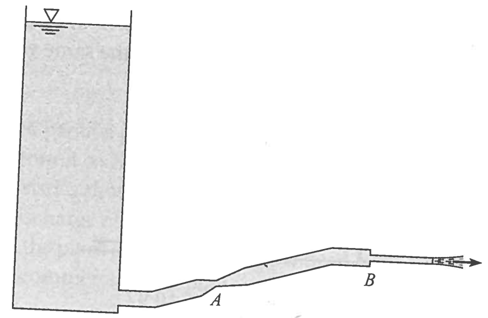
PROBLEM 10.81

10.82 Both pipes in the system shown have an equivalent sand roughness k_s of 0.10 mm and a flow rate of 0.1 m^3/s, with D_1 = 12 cm, L_1 = 60 m, D_2 = 24 cm, and L_2 = 120 m. Determine the difference in the water-surface elevation between the two reservoirs.



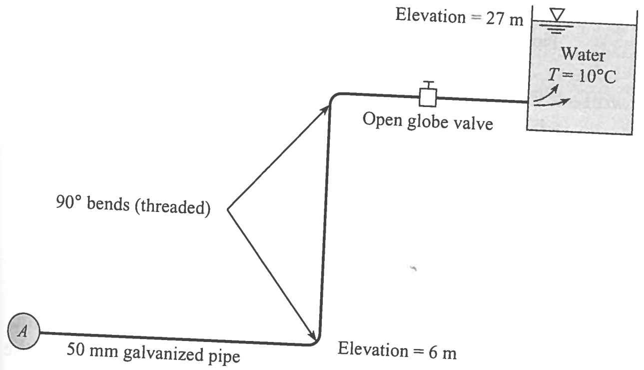
PROBLEM 10.82

10.83 Liquid discharges from a tank through the piping system shown. There is a venturi section at A and a sudden contraction at B. The liquid discharges to the atmosphere. Sketch the energy and hydraulic gradelines. Where might cavitation occur?



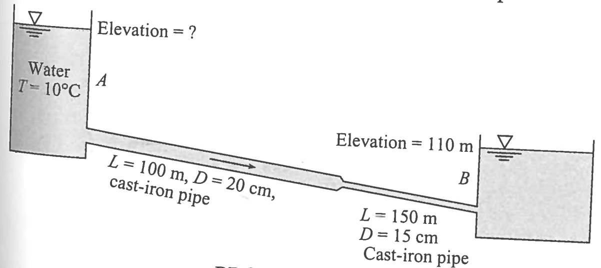
PROBLEM 10.83

10.84 The steel pipe shown carries water from the main pipe A to the reservoir and is 50 mm in diameter and 72 m long. What must be the pressure in pipe A to provide a flow of 190 lpm?



PROBLEM 10.84

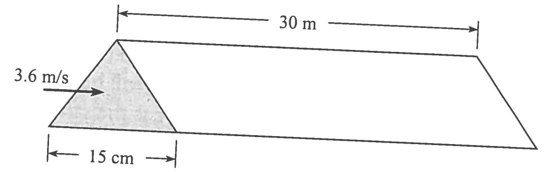
10.85 If the water surface elevation in reservoir B is 110 m, what must be the water surface elevation in reservoir A if a flow of 0.03 m^3/s is to occur in the cast-iron pipe? Draw the HGL and the EGL, including relative slopes and changes in slope.



PROBLEM 10.85

Nonround Conduits (§10.9)

10.86 Air at 60°F and atmospheric pressure flows in a horizontal duct with a cross section corresponding to an equilateral triangle (all sides equal). The duct is 30 m long, and the dimension of a side is 150 mm. The duct is constructed of galvanized iron (k_s = 0.15 mm). The mean velocity in the duct is 3.6 m/s. What is the pressure drop over the 30-m length?

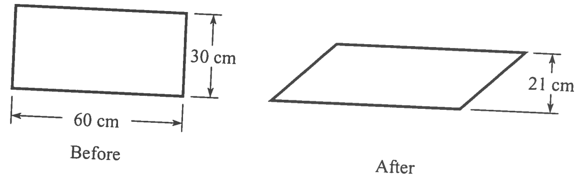


PROBLEM 10.86

10.87 A cold-air duct 100 cm by 15 cm in cross section is 100 m long and made of galvanized iron. This duct is to carry air at a rate of 6 m^3/s at a temperature of 15°C and atmospheric pressure. What is the power loss in the duct?

10.88 Air (20°C) flows with a speed of 10 m/s through a horizontal rectangular air-conditioning duct. The duct is 20 m long and has a cross section of 1. Calculate (a) the pressure drop in meters of water and (b) the power in watts needed to overcome head loss. Assume the roughness of the duct is k_s = 0.004 mm. Neglect component head losses.

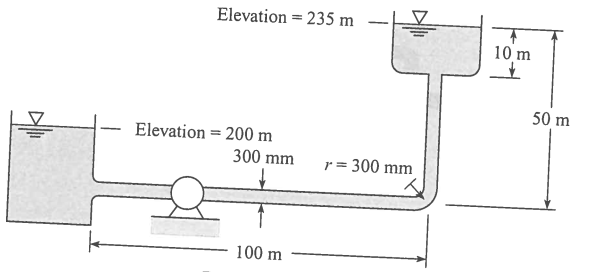
10.89 An air-conditioning system is designed to have a duct with a rectangular cross section 30 cm by 60 cm, as shown. During construction, a truck driver backed into the duct and made it a trapezoidal section, as shown. The contractor, behind schedule, installed it anyway. For the same pressure drop along the pipe, what will be the ratio of the velocity in the trapezoidal duct to that in the rectangular duct? Assume the Darcy-Weisbach resistance coefficient is the same for both ducts.



PROBLEM 10.89

Modeling Pumps in Systems (§10.10)

10.90 What power must be supplied by the pump to the flow if water (T = 20°C) is pumped through the 300-mm steel pipe from the lower tank to the upper one at a rate of 0.4 m^3/s?

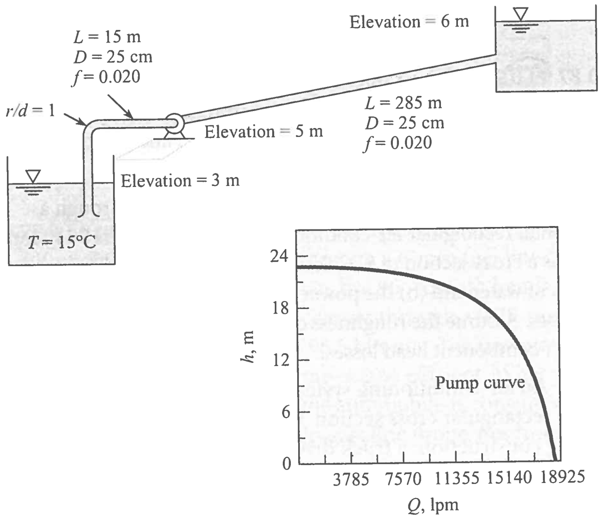


PROBLEM 10.90

10.91 If the pump for Fig. 10.20b is installed in the system of Prob. 10.90, what will be the rate of discharge of water from the lower tank to the upper one?

10.92 A pump that has the characteristic curve shown in the accompanying graph is to be installed as shown. What will be the discharge of water in the system?

10.93 If the liquid of Prob. 10.92 is a superliquid (zero head loss occurs with the flow of this liquid), then what will be the pumping rate, assuming that the pump curve is the same?

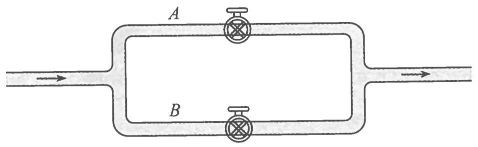


PROBLEMS 10.92, 10.93

Pipes in Parallel and in Networks (§10.10)

10.94 WILEY PLUS A pipe system consists of a gate valve, wide open ($K_v = 0.2$), in line A and a globe valve, wide open ($K_v = 10$), in line B. The cross-sectional area of pipe A is half of the cross-sectional area of pipe B. The head loss due to the junction, elbows, and pipe friction are negligible compared with the head loss through the valves. Find the ratio of the discharge in line B to that in line A.

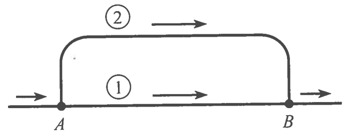
10.95 A flow is divided into two branches as shown. A gate valve, half open, is installed in line A, and a globe valve, fully open, is installed in line B. The head loss due to friction in each branch is negligible compared with the head loss across the valves. Find the ratio of the velocity in line A to that in line B (include elbow losses for threaded pipe fittings).



PROBLEMS 10.94, 10.95

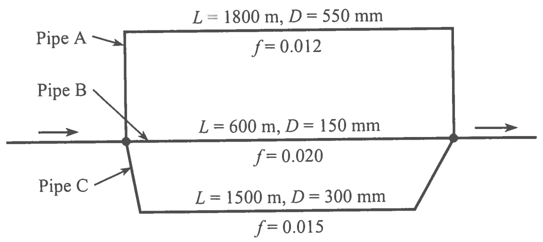
10.96 WILEY PLUS In the parallel system shown, pipe 1 is 1200 m long and is 50 cm in diameter. Pipe 2 is 1500 m long and 35 cm in diameter. Assume f is the same in both pipes. What is the division of the flow of water at 10°C if the flow rate will be 1.2 m^3/s?

10.97 Pipes 1 and 2 are the same kind (cast-iron pipe), but pipe 2 is three times as long as pipe 1. They are the same diameter (30 cm). If the discharge of water in pipe 2 is 0.03 m^3/s, then what will be the discharge in pipe 1? Assume the same value of f in both pipes.



PROBLEMS 10.93, 10.97

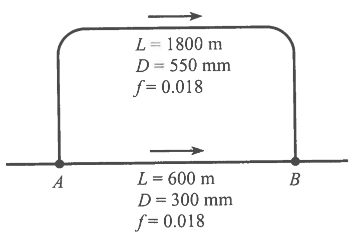
10.98 Water flows from left to right in this parallel pipe system. The pipe having the greatest velocity is (a) pipe A, (b) pipe B, or (c) pipe C.



PROBLEM 10.98

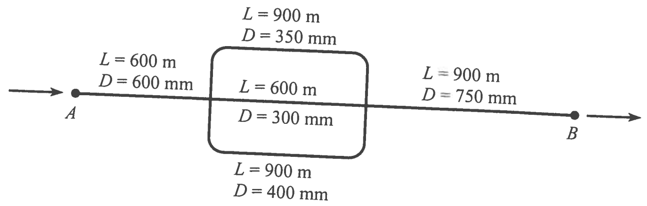
10.99 Two pipes are connected in parallel. One pipe is twice the diameter of the other and four times as long. Assume that f in the larger pipe is 0.010 and f in the smaller one is 0.012. Determine the ratio of the discharges in the two pipes.

10.100 WILEY PLUS With a total flow of 0.4 m^3/s, determine the division of flow and the head loss from A to B.



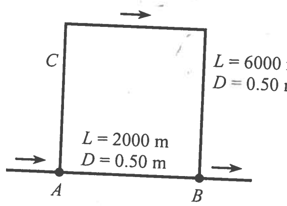
PROBLEM 10.100

10.101 WILEY PLUS The pipes shown in the system are all concrete. With a flow of 0.7 m^3/s of water, find the head loss and the division of flow in the pipes from A to B. Assume $f = 0.030$ for all pipes.



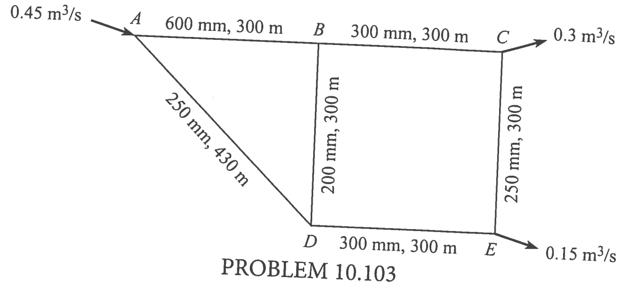
PROBLEM 10.101

10.102 A parallel pipe system is set up as shown. Flow occurs from A to B. To augment the flow, a pump having the characteristics shown in Fig. 10.20b is installed at point C. For a total discharge of 0.60 m^3/s, what will be the division of flow between the pipes and what will be the head loss between A and B? Assume commercial steel pipe.



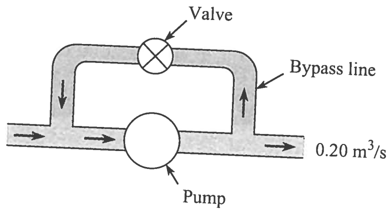
PROBLEM 10.102

10.103 For the given source and loads shown, how will the flow be distributed in the simple network, and what will be the pressures at the load points if the pressure at the source is 400 kPa? Assume horizontal pipes and $f = 0.012$ for all pipes.



PROBLEM 10.103

10.104 Frequently in the design of pump systems, a bypass line will be installed in parallel to the pump so that some of the fluid can recirculate as shown. The bypass valve then controls the flow rate in the system. Assume that the head-versus-discharge curve for the pump is given by $h_p = 100 - 100Q$, where h_p is in meters and Q is in m^3/s. The bypass line is 10 cm in diameter. Assume the only head loss is that due to the valve, which has a head-loss coefficient of 0.2. The discharge leaving the system is 0.2 m^3/s. Find the discharge through the pump and bypass line.



PROBLEM 10.104