8.1 Water flows through a 3-in-diameter pipe at a velocity of 10 ft/s. Find the **(*a*)** volume flow rate in cfs and gpm, **(*b*)** weight flow rate, and **(*c*)** mass flow rate.

(*a*) $$Q = Av = [(\pi)(\tfrac{3}{12})^2/4](10) = 0.4909 \text{ cfs} = 0.4909/0.002228 = 220 \text{ gpm}$$

(*b*) $$W = \gamma Av = 62.4[(\pi)(\tfrac{3}{12})^2/4](10) = 30.6 \text{ lb/s}$$

(*c*) $$M = \rho Av = 1.94[(\pi)(\tfrac{3}{12})^2/4](10) = 0.952 \text{ slug/s}$$

8.2 Benzene flows through a 100-mm-diameter pipe at a mean velocity of 3.00 m/s. Find the **(*a*)** volume flow rate in m^3/s and L/min, **(*b*)** weight flow rate, and **(*c*)** mass flow rate.

(*a*) $$Q = Av = [(\pi)(\tfrac{100}{1000})^2/4](3.00) = 0.0236 \text{ m}^3/\text{s} = 0.0236/0.00001667 = 1416 \text{ L/min}$$

(*b*) $$W = \gamma Av = 8.62[(\pi)(\tfrac{100}{1000})^2/4](3.00) = 0.203 \text{ kN/s}$$

(*c*) $$M = \rho Av = 879[(\pi)(\tfrac{100}{1000})^2/4](3.00) = 20.7 \text{ kg/s}$$

8.4 Assume the conduit shown in Fig. 8-1 has (inside) diameters of 12 in and 18 in at sections 1 and 2, respectively. If water is flowing in the conduit at a velocity of 16.6 ft/s at section 2, find the (*a*) velocity at section 1, (*b*) volume flow rate at section 1, (*c*) volume flow rate at section 2, (*d*) weight flow rate, and (*e*) mass flow rate.

(a) $$A_1 v_1 = A_2 v_2 \qquad [(\pi)(\tfrac{12}{12})^2/4](v_1) = [(\pi)(\tfrac{18}{12})^2/4](16.6) \qquad v_1 = 37.3 \text{ ft/s}$$

(b) $$Q_1 = A_1 v_1 = [(\pi)(\tfrac{12}{12})^2/4](37.3) = 29.3 \text{ ft}^3/\text{s}$$

(c) $Q_2 = A_2 v_2 = [(\pi)(\tfrac{18}{12})^2/4](16.6) = 29.3 \text{ ft}^3/\text{s}$. (Since the flow in incompressible, the flow rate is the same at sections 1 and 2.)

(d) $$W = \gamma A_1 v_1 = 62.4[(\pi)(\tfrac{12}{12})^2/4](37.3) = 1828 \text{ lb/s}$$

(e) $$M = \rho A_1 v_1 = 1.94[(\pi)(\tfrac{12}{12})^2/4](37.3) = 56.8 \text{ slugs/s}$$

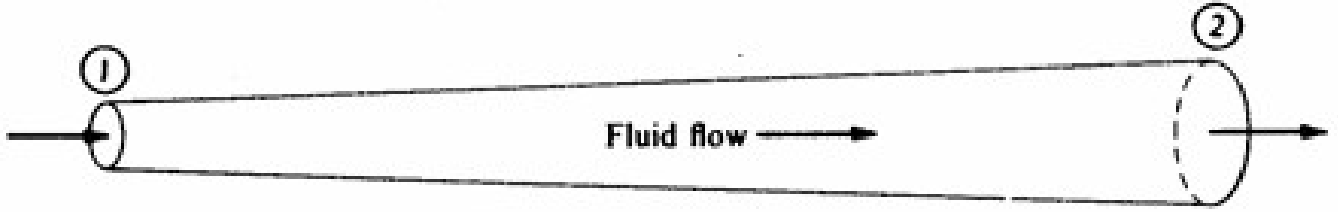


Fig. 8-1

8.6 Water enters the mixing device shown in Fig. 8-2 at 150 L/s through pipe A, while oil with specific gravity 0.8 is forced in at 30 L/s through pipe B. If the liquids are incompressible and form a homogeneous mixture of oil globules in water, find the average velocity and density of the mixture leaving through the 30-cm-diameter pipe C.

$$M = \rho A v = \rho Q \qquad \sum (\text{mass flow in unit time})_{in} = \sum (\text{mass flow in unit time})_{out}$$

$$(1000)(0.15) + [(0.8)(1000)](0.03) = (\rho)[(\pi)(0.30)^2/4](v) \qquad \rho v = 2462 \text{ kg/m}^2 \cdot \text{s}$$

We can assume no chemical reaction between oil and water and its mixture is incompressible; it is clear that volume is conserved. Hence, $Q = 0.15 + 0.03 = 0.18 \text{ m}^3/\text{s}$; $Q = Av$, $0.18 = [(\pi)(0.30)^2/4](v)$, $v_C = 2.55 \text{ m/s}$; $\rho_C = 2462/2.55 = 965 \text{ kg/m}^3$.

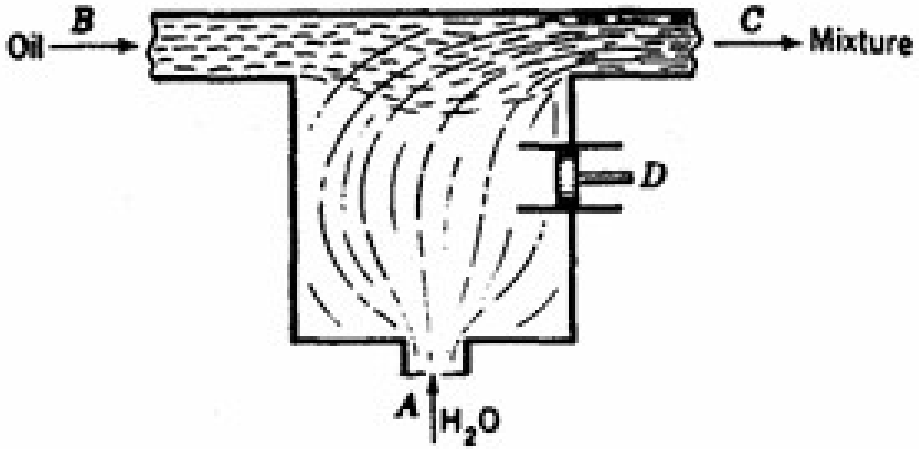


Fig. 8-2

8.7 Water flows into a cylindrical tank (Fig. 8-3) through pipe 1 at the rate of 25 ft/s and leaves through pipes 2 and 3 at 10 ft/s and 12 ft/s, respectively. At 4 is an open air vent. Inside pipe diameters are: $D_1 = 3$ in, $D_2 = 2$ in, $D_3 = 2.5$ in, $D_4 = 2$ in. Calculate **(a)** dh/dt; **(b)** the average velocity of airflow through vent 4, assuming that the flow is incompressible.

(a) With the entire volume of the tank as control volume,

$$M = \rho A v = \rho Q \qquad \sum (\text{mass flow in unit time})_{in} = \sum (\text{mass flow in unit time})_{out}$$

$$(\rho)[(\pi)(\tfrac{3}{12})^2/4](25) = (\rho)[(\pi)(\tfrac{3}{12})^2/4](10) + (\rho)[(\pi)(2.5/12)^2/4](12) + (\rho)[(\pi)(2)^2/4](dh/dt)$$

$$dh/dt = 0.1910 \text{ ft/s}$$

(b) Consider only air in the control volume. It must be conserved. Hence, $(\rho_{air})[(\pi)(\tfrac{2}{12})^2/4](v) = (\rho_{air})[(\pi)(2)^2/4](0.1484)$, $v = 21.4$ ft/s.

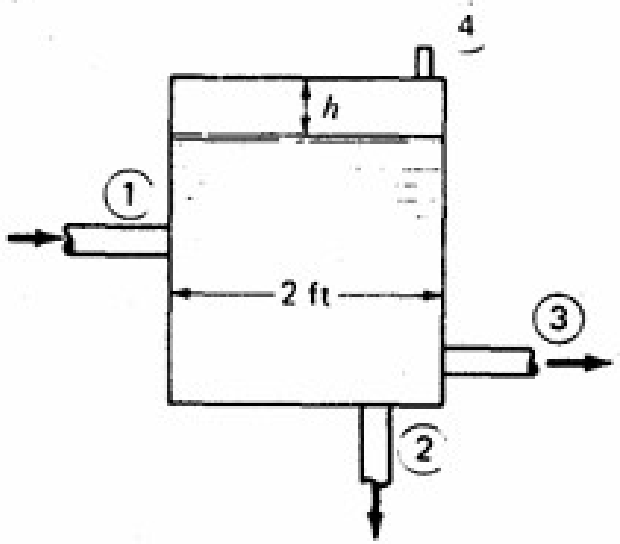


Fig. 8-3

8.51 In Fig. 8-21, water flows from A, where the diameter is 12 in, to B, where the diameter is 24 in, at the rate of 13.2 cfs. The pressure head at A is 22.1 ft. Considering no loss of energy from A to B, find the pressure head at B.

$$p_A/\gamma + v_A^2/2g + z_A = p_B/\gamma + v_B^2/2g + z_B \qquad v_A = Q/A_A = 13.2/[(\pi)(\tfrac{12}{12})^2/4] = 16.81 \text{ ft/s}$$

$$v_B = Q/A_B = 13.2/[(\pi)(\tfrac{24}{12})^2/4] = 4.202 \text{ ft/s}$$

$$22.1 + 16.81^2/[(2)(32.2)] + 0 = p_B/\gamma + 4.202^2/[(2)(32.2)] + (25.0 - 10.0) \qquad p_B/\gamma = 11.2 \text{ ft of water}$$

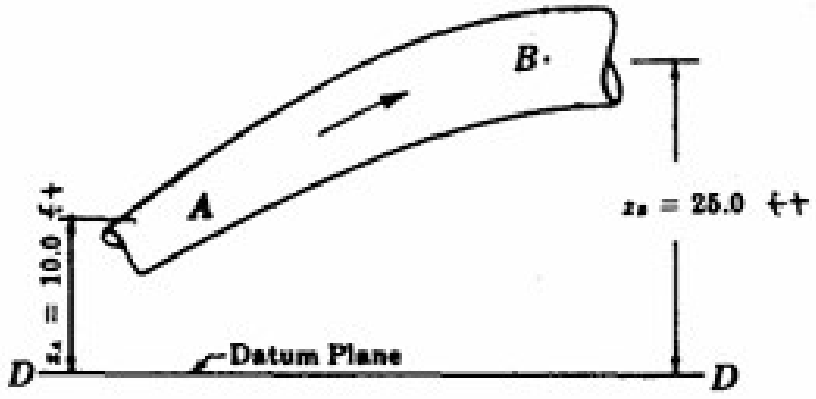


Fig. 8-21

8.67 An 8-in-diameter horizontal pipe is attached to a reservoir, as shown in Fig. 8-26. If the total head loss between the water surface in the reservoir and the water jet at the end of the pipe is 6.0 ft, what are the velocity and flow rate of the water being discharged from the pipe?

I

$$p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L \qquad 0 + 0 + 15 = 0 + v_2^2/[(2)(32.2)] + 0 + 6.0$$

$$v_2 = 24.1 \text{ ft/s} \qquad Q = A_2 v_2 = [(\pi)(\tfrac{8}{12})^2/4](24.1) = 8.41 \text{ ft}^3/\text{s}$$

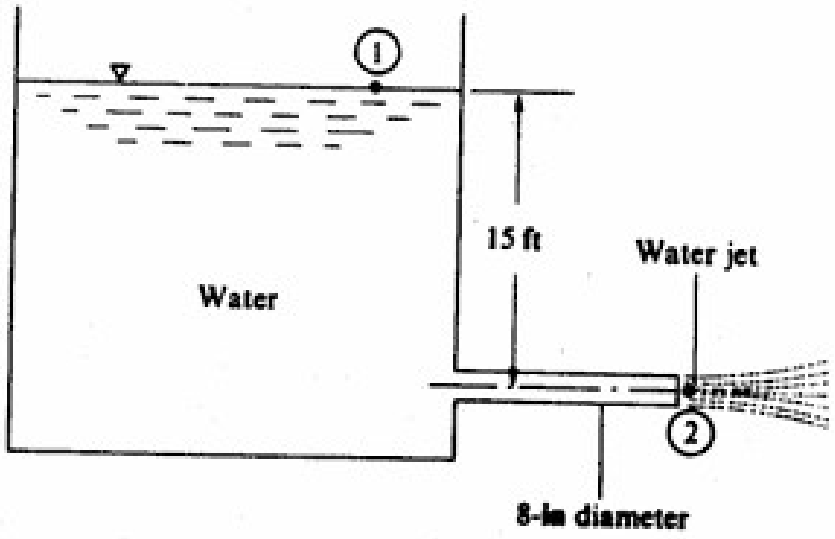


Fig. 8-26

8.68 A 50-mm-diameter siphon is drawing oil (s.g. = 0.82) from an oil reservoir, as shown in Fig. 8-27. If the head loss from point 1 to point 2 is 1.50 m and from point 2 to point 3 is 2.40 m, find the discharge of oil from the siphon and the oil pressure at point 2.

$$p_1/\gamma + v_1^2/2g + z_1 = p_3/\gamma + v_3^2/2g + z_3 + h_L \qquad 0 + 0 + 5.00 = 0 + v_3^2/[(2)(9.807)] + 0 + 3.90$$

$$v_3 = 4.645 \text{ m/s} \qquad Q = A_3 v_3 = [(\pi)(\tfrac{50}{1000})^2/4](4.645) = 0.00912 \text{ m}^3/\text{s}$$

$$p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L \qquad 0 + 0 + 5.00 = p_2/\gamma + 4.645^2/[(2)(9.807)] + 7.00 + 1.50$$

$$p_2/\gamma = -4.60 \text{ m} \qquad p_2 = [(0.82)(9.79)](-4.60) = -36.9 \text{ kN/m}^2 \quad \text{or} \quad -36.9 \text{ kPa}$$

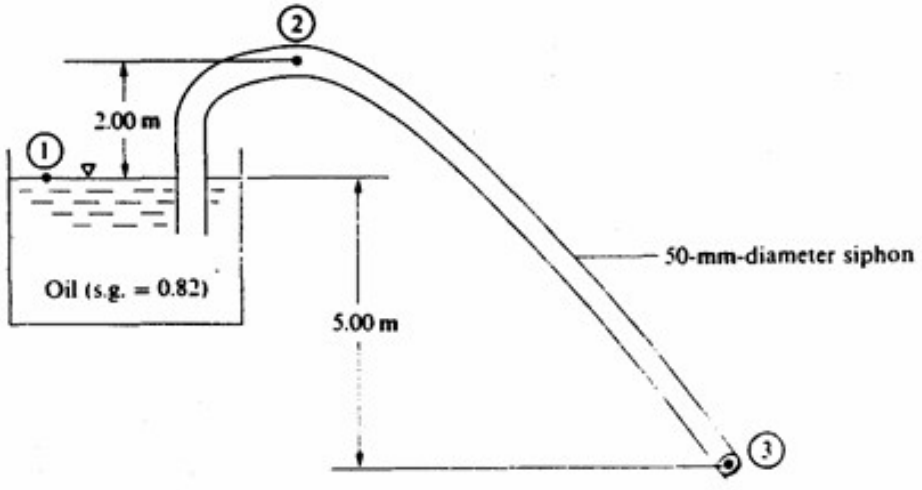


Fig. 8-27

8.77 Determine the velocity and pressure at section 2 and section 3 if water flows steadily through the pipe system shown in Fig. 8-36. Assume a head loss of 6.0 ft from section 1 to section 2 and of 15.0 ft from section 2 to section 3.

I

$$A_1v_1 = A_2v_2 \qquad [(\pi)(\tfrac{16}{12})^2/4](5.0) = [(\pi)(\tfrac{8}{12})^2/4](v_2) \qquad v_2 = 20.0 \text{ ft/s}$$

$$p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L$$

$$(25)(144)/62.4 + 5.0^2/[(2)(32.2)] + 20 = (p_2)(144)/62.4 + 20.0^2/[(2)(32.2)] + 15 + 6.0$$

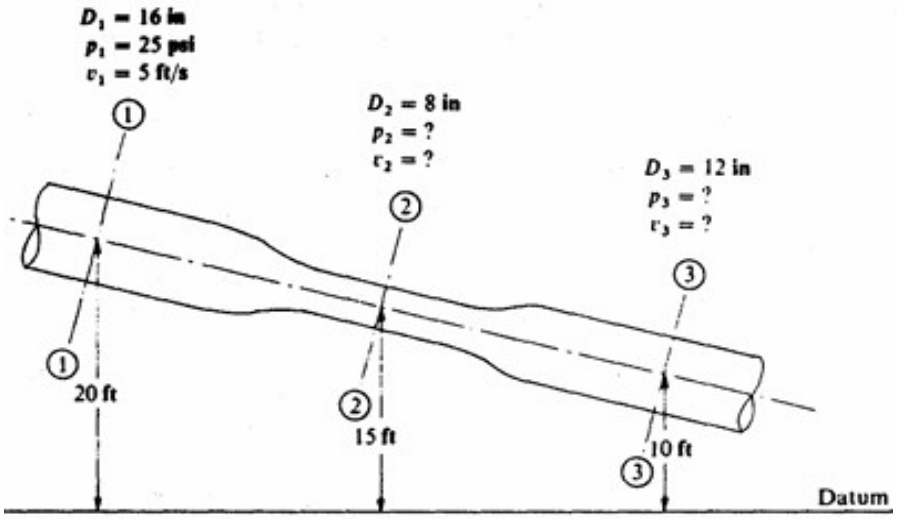
$$p_2 = 22.0 \text{ lb/in}^2 \qquad A_1v_1 = A_3v_3$$

$$[(\pi)(\tfrac{16}{12})^2/4](5.0) = [(\pi)(\tfrac{12}{12})^2/4](v_3) \qquad v_3 = 8.99 \text{ ft/s}$$

$$p_1/\gamma + v_1^2/2g + z_1 = p_3/\gamma + v_3^2/2g + z_3 + h_L$$

$$(25)(144)/62.4 + 5.0^2/[(2)(32.2)] + 20 = (p_3)(144)/62.4 + 8.89^2/[(2)(32.2)] + 10 + (15.0 + 6.0)$$

$$p_3 = 19.9 \text{ lb/in}^2$$



8.101 The horizontal wye fitting in Fig. 8-58 splits Q_1 into two equal flow rates. At section 1, $Q_1 = 4\ \text{ft}^3/\text{s}$ and $p_1 = 20$ psig. Neglecting losses, compute pressures p_2 and p_3.

$$p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L \qquad v_1 = Q_1/A_1 = 4/[(\pi)(\tfrac{6}{12})^2/4] = 20.37\ \text{ft/s}$$

$$v_2 = Q_2/A_2 = \tfrac{4}{2}/[(\pi)(\tfrac{4}{12})^2/4] = 22.92\ \text{ft/s}$$

$$(20)(144)/62.4 + 20.37^2/[(2)(32.2)] + 0 = (p_2)(144)/62.4 + 22.92^2/[(2)(32.2)] + 0 + 0$$

$p_2 = 19.3$ psig $\qquad p_1/\gamma + v_1^2/2g + z_1 = p_3/\gamma + v_3^2/2g + z_3 + h_L \qquad v_3 = Q_3/A_3 = \tfrac{4}{2}/[(\pi)(\tfrac{3}{12})^2/4] = 40.74\ \text{ft/s}$

$$(20)(144)/62.4 + 20.37^2/[(2)(32.2)] + 0 = (p_3)(144)/62.4 + 40.74^2/[(2)(32.2)] + 0 + 0 \qquad p_3 = 11.6\ \text{psig}$$

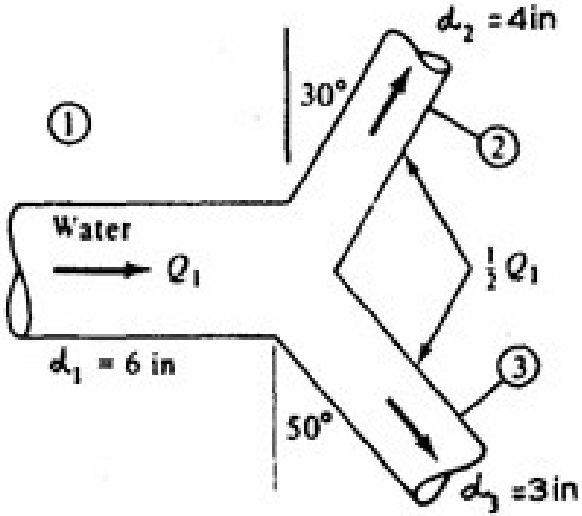


Fig. 8-58

8.103 In the water flow over the spillway in Fig. 8-59, the velocity is uniform at sections 1 and 2 and the pressure approximately hydrostatic. Neglecting losses, compute v_1 and v_2. Assume unit width.

$$p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L \qquad 0 + v_1^2/2g + 6 = 0 + v_2^2/2g + 1 + 0$$

$$A_1 v_1 = A_2 v_2 \qquad [(6)(1)](v_1) = [(1)(1)](v_2) \qquad v_2 = 6v_1$$

$$v_1^2/[(2)(9.807)] + 6 = (6v_1)^2/[(2)(9.807)] + 1 \qquad v_1 = 1.67 \text{ m/s} \qquad v_2 = (6)(1.67) = 10.02 \text{ m/s}$$

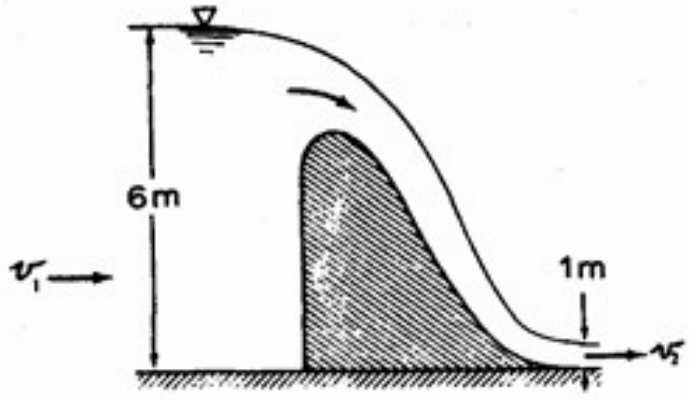


Fig. 8-59

8.184 For the water channel flow down the sloping ramp of Fig. 8-60, $h_1 = 1$ m, $H = 3$ m, and $v_1 = 4$ m/s. The flow is uniform at 1 and 2. Neglecting losses, find the downstream depth h_2 and show that three solutions are possible, of which only two are realistic. Neglect friction.

If $p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L$ $\quad 0 + 4^2/[(2)(9.807)] + (3 + 1) = 0 + v_2^2/[(2)(9.807)] + h_2 + 0$

$$A_1 v_1 = A_2 v_2 \qquad [(1)(1)](4) = [(h_2)(1)](v_2) \qquad v_2 = 4/h_2$$

$$4^2/[(2)(9.807)] + 4 = (4/h_2)^2/[(2)(9.807)] + h_2 \qquad h_2^3 - 4.816h_2^2 + 0.8157 = 0$$

There are three mathematical solutions to this equation:

$h_2 = 4.78$ m (subcritical)

$h_2 = 0.432$ m (supercritical)

$h_2 = -0.396$ m (impossible)



Fig. 8-60

8.185 For water flow up the sloping channel in Fig. 8-61, $h_1 = 0.5$ ft, $v_1 = 15$ ft/s, and $H = 2$ ft. Neglect losses and assume uniform flow at 1 and 2. Find the downstream depth h_2 and show that three solutions are possible, of which only two are realistic.

I $p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L \qquad 0 + 15^2/[(2)(32.2)] + 0.5 = 0 + v_2^2/[(2)(32.2)] + (2 + h_2) + 0$

$$A_1 v_1 = A_2 v_2 \qquad [(0.5)(1)](15) = [(h_2)(1)](v_2) \qquad v_2 = 7.5/h_2$$

$$15^2/[(2)(32.2)] + 0.5 = (7.5/h_2)^2/[(2)(32.2)] + (2 + h_2) \qquad h_2^3 - 1.994h_2^2 + 0.8734 = 0$$

There are three mathematical solutions to this equation:

$h_2 = 1.69$ ft (subcritical)

$h_2 = 0.887$ ft (supercritical)

$h_2 = -0.582$ ft (impossible)

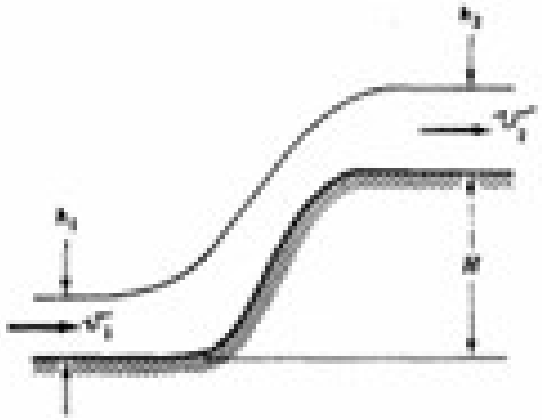


Fig. 8-61

9.280 A capillary tube of inside diameter 6 mm connects tank A and open container B, as shown in Fig. 9-50. The liquid in A, B, and capillary CD is water having a specific weight of 9780 N/m^3 and a viscosity of 0.0008 kg/(m · s). The pressure $p_A = 34.5$ kPa gage. Which direction will the water flow? What is the flow rate?

I Assume laminar flow from B to A.

$$\frac{p_B}{\gamma}+\frac{v_B^2}{2g}+z_B=\frac{p_A}{\gamma}+\frac{v_A^2}{2g}+z_A+h_L \qquad h_f=\frac{128\mu LQ}{\pi\gamma D^4}=\frac{(128)(0.0008)(4.3)(Q)}{(\pi)(9780)(\frac{6}{1000})^4}=11\,058Q$$

$$0+0+(1.4+4.3\sin 45°)=34.5/9.79+0+1+11\,058Q$$

$$Q=-7.55\times10^{-6}\ \text{m}^3/\text{s} \quad \text{or} \quad -7.55\times10^{-3}\ \text{L/s}$$

Since Q is negative, the flow must be from A to B. Check for laminar flow: $v = Q/A = (7.55 \times 10^{-6})/[(\pi)(\frac{6}{1000})^2/4] = 0.2670$ m/s, $N_R = \rho Dv/\mu = (9780/9.807)(\frac{6}{1000})(0.2670)/0.0008 = 1997$ (laminar).

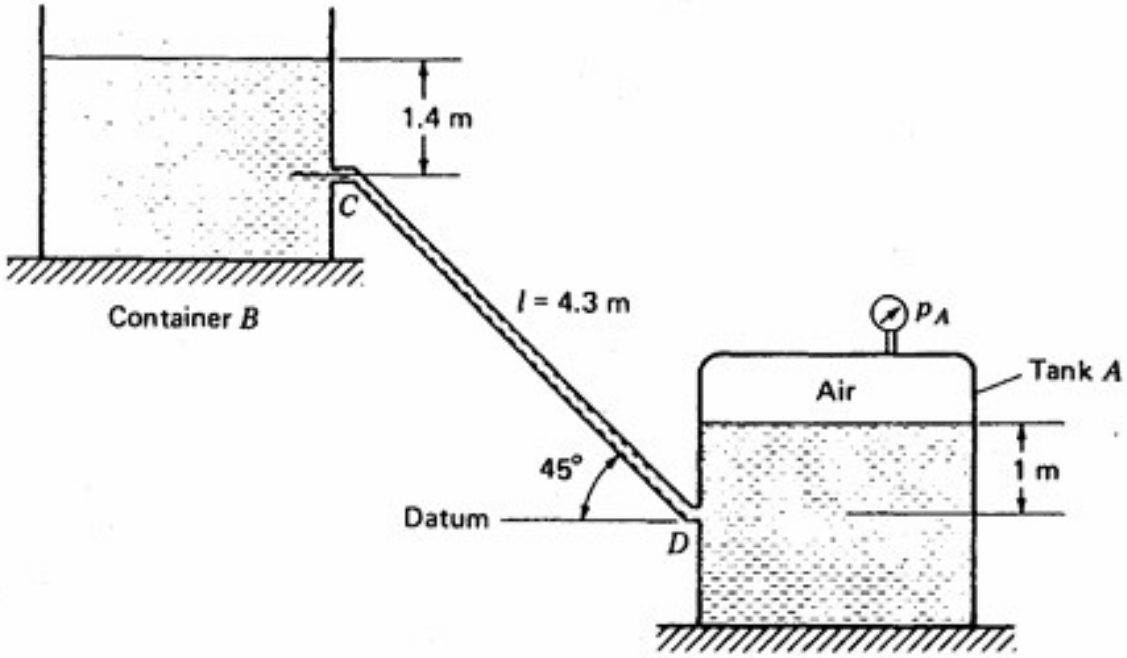


Fig. 9-50

9.17 If 140 L/s of water flows through the system shown in Fig. 9-6, calculate the total head loss between 2 and 3.

$$p_2/\gamma + v_2^2/2g + z_2 = p_3/\gamma + v_3^2/2g + z_3 + h_L$$

$$v_2 = Q/A_2 = (140 \times 10^{-3})/[(\pi)(0.300)^2/4] = 1.981 \text{ m/s} \qquad v_3 = Q/A_3 = (140 \times 10^{-3})/[(\pi)(0.150)^2/4] = 7.922 \text{ m/s}$$

$$p_2/9.79 + 1.981^2/[(2)(9.807)] + 0 = 0 + 7.922^2/[(2)(9.807)] + 15 + h_L \qquad h_L = p_2/9.79 - 18.00$$

$$p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L \qquad 0 + 0 + 30 = p_2/9.79 + 1.981^2/[(2)(9.807)] + 0 + 0$$

$$p_2/9.79 = 29.80 \text{ m} \qquad h_L = 29.80 - 18.00 = 11.80 \text{ m}$$

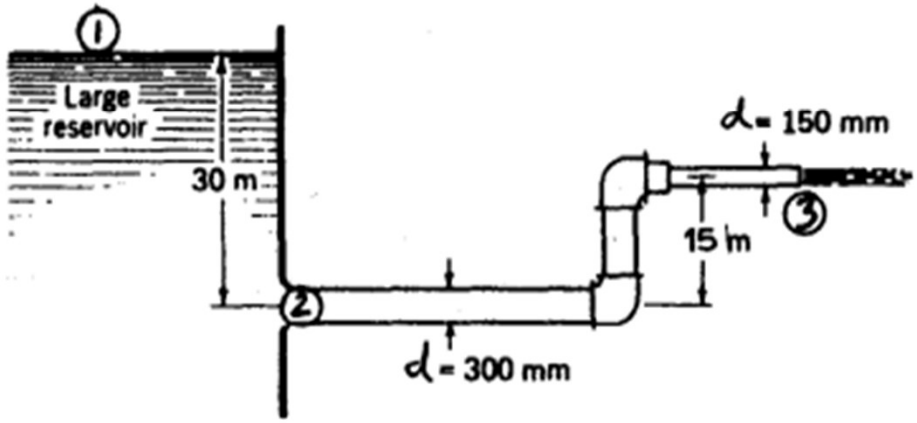


Fig. 9-6

Compute the velocity and Reynolds number to see if the flow is laminar. $\nu_{oil} = 1 \times 10^{-4}$ ft^2/s. Neglect entrance losses to the pipe.

$p_2/\gamma + v_2^2/2g + z_2 = p_3/\gamma + v_3^2/2g + z_3 + h_L \qquad p_2/62.4 + v_2^2/2g + 0 = 0 + v_3^2/2g + 0 + h_f \qquad v_2^2/2g = v_3^2/2g$

$$p_2/62.4 = h_f \tag{1}$$

$$Q = \frac{\pi \rho g d^4 h_f}{128 \mu L}$$

$$h_f = \frac{128 Q \mu L}{\pi \rho g d^4} = \frac{128[(\pi d^2/4)(v_2)]\mu L}{\pi \rho g d^4} = \frac{32 v_2 \nu L}{g d^2} = \frac{(32)(v_2)(1 \times 10^{-4})(7000)}{(32.2)(3/12)^2} = 11.13 v_2 \tag{2}$$

$p_1/\gamma + v_1^2/2g + z_1 = p_2/\gamma + v_2^2/2g + z_2 + h_L \qquad 0 + 0 + 10 = p_2/62.4 + v_2^2/[(2)(32.2)] + 0 + 0$

$$p_2/62.4 = 10 - v_2^2/[(2)(32.2)] \tag{3}$$

Equating h_f from Eqs. (*1*) and (*2*),

$$p_2/62.4 = 11.13 v_2 \tag{4}$$

Equating $p_2/62.4$ from Eqs. (*3*) and (*4*), $11.13 v_2 = 10 - v_2^2/[(2)(32.2)]$, $v_2^2 + 716.8 v_2 - 644 = 0$, $v_2 = 0.8973$ ft/s; $Q = Av = [(\pi)(\frac{3}{12})^2/4](0.8973) = 0.0440$ ft^3/s; $N_R = dv/\nu = (\frac{3}{12})(0.8973)/(1 \times 10^{-4}) = 2243$ (barely laminar).

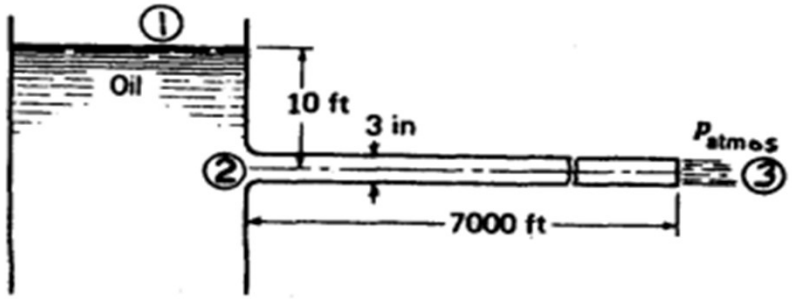


Fig. 9-5