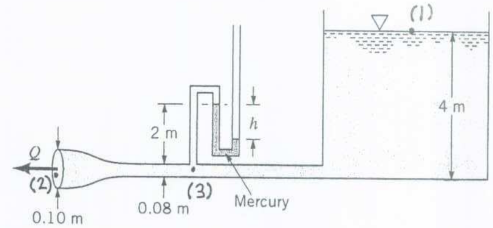
3.68

3.68 Water flows steadily from the large open tank shown in Fig. P3.68. If viscous effects are negligible, determine (**a**) the flowrate, Q, and (**b**) the manometer reading, h.



■ FIGURE P3.68

(a) From the Bernoulli equation,

$$p_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = p_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2, \text{ where } p_1 = p_2 = 0,\ V_1 = 0,\ z_1 = 4\,m, \text{ and } z_2 = 0.$$

Thus,

$$\gamma z_1 = \frac{1}{2}\rho V_2^2, \text{ or } \rho g z_1 = \frac{1}{2}\rho V_2^2 \text{ so that } V_2 = \sqrt{2 g z_1}$$

or

$$V_2 = \sqrt{2(9.81\,m/s^2)(4\,m)} = 8.86\,m/s$$

Hence,

$$Q = A_2 V_2 = \frac{\pi}{4}(0.10\,m)^2(8.86\,m/s) = \underline{\underline{0.0696\,m^3/s}}$$

(b) From the Bernoulli equation,

$$p_3 + \frac{1}{2}\rho V_3^2 + \gamma z_3 = p_2 + \frac{1}{2}\rho V_2^2 + \gamma z_3, \text{ where } z_2 = z_3 \text{ and } p_2 = 0$$

so that

$$p_3 = \frac{1}{2}\rho(V_2^2 - V_3^2)$$

Also, $A_2 V_2 = A_3 V_3$ so that $V_3 = \frac{A_2}{A_3} V_2 = \left(\frac{D_2}{D_3}\right)^2 V_2 = \left(\frac{0.1\,m}{0.08\,m}\right)^2 8.86\,m/s = 13.84\,m/s$

Hence,

$$p_3 = \frac{1}{2}(999\,kg/m^3)\left[(8.86\,m/s)^2 - (13.84\,m/s)^2\right] = -56{,}500\,N/m^2 \qquad (1)$$

Also, from the manometer,

$$p_3 = -\gamma_{Hg} h + \gamma_{H_2O}(2\,m + (0.08/2)\,m)$$

$$= -(133 \times 10^3\,N/m^3)h + (9.80 \times 10^3\,N/m^3)(2.04\,m)$$

$$= -133 \times 10^3 h + 1.99 \times 10^4\ N/m^2, \text{ where } h \sim m \qquad (2)$$

Thus, from Eqs. (1) and (2):

$$-5.65 \times 10^4\,N/m^2 = -133 \times 10^3 h + 1.99 \times 10^4\,N/m^2$$

or

$$h = \underline{\underline{0.574\,m}}$$