6.78 In Fig. P6.78 the connecting pipe is commercial steel 6 cm in diameter. Estimate the flow rate, in m^3/h, if the fluid is water at 20°C. Which way is the flow?

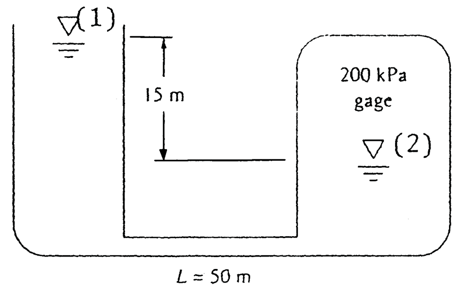

Fig. P6.78

Solution: For water, take $\rho = 998\ kg/m^3$ and $\mu = 0.001$ kg/m·s. For commercial steel, take $\varepsilon \approx 0.046$ mm, hence $\varepsilon/d = 0.046/60 \approx 0.000767$. With p_1, V_1, and V_2 all ≈ 0, the energy equation between surfaces (1) and (2) yields

$$0 + 0 + z_1 \approx \frac{p_2}{\rho g} + 0 + z_2 + h_f, \quad \text{or} \quad h_f = 15 - \frac{200000}{998(9.81)} \approx -5.43\ \text{m}\ \textbf{(flow to left)} \leftarrow$$

$$\text{Guess turbulent flow:}\quad h_f = f\frac{L}{d}\frac{V^2}{2g} = f\frac{50}{0.06}\frac{V^2}{2(9.81)} = 5.43, \quad \text{or:} \quad fV^2 \approx 0.1278$$

$$\frac{\varepsilon}{d} = 0.00767, \quad \text{guess } f_{\text{fully rough}} \approx 0.0184, \quad V \approx \left(\frac{0.1278}{0.0184}\right)^{1/2} \approx 2.64\ \frac{m}{s}, \quad Re = 158000$$

$$f_{\text{better}} \approx 0.0204, \quad V_{\text{better}} = 2.50\ \frac{m}{s}, \quad Re_{\text{better}} \approx 149700, \quad f_{\text{3rd iteration}} \approx 0.0205\ \text{(converged)}$$

The iteration converges to

$$f \approx 0.0205,\ V \approx 2.49\ m/s,\ Q = (\pi/4)(0.06)^2(2.49) = 0.00705\ m^3/s = \mathbf{25\ m^3/h} \leftarrow \quad \textit{Ans.}$$

6.79 A garden hose is used as the return line in a waterfall display at the mall. In order to select the proper pump, you need to know the hose wall roughness, which is not supplied by the manufacturer. You devise a simple experiment: attach the hose to the drain of an above-ground pool whose surface is 3 m above the hose outlet. You estimate the minor loss coefficient in the entrance region as 0.5, and the drain valve has a minor-loss equivalent length of 200 diameters when fully open. Using a bucket and stopwatch, you open the valve and measure a flow rate of 2.0E–4 m^3/s for a hose of inside diameter 1.5 cm and length 10 m. Estimate the roughness height of the hose inside surface.

Solution: First evaluate the average velocity in the hose and its Reynolds number:

$$V = \frac{Q}{A} = \frac{2.0E\text{–}4}{(\pi/4)(0.015)^2} = 1.13\ \frac{m}{s}, \quad Re_d = \frac{\rho V d}{\mu} = \frac{998(1.13)(0.015)}{0.001} = 16940\ (\textit{turbulent})$$