6.21 In Tinyland, houses are less than a foot high! The rainfall is laminar! The drainpipe in Fig. P6.21 is only 2 mm in diameter. (a) When the gutter is full, what is the rate of draining? (b) The gutter is designed for a sudden rainstorm of up to 5 mm per hour. For this condition, what is the maximum roof area that can be drained successfully? (c) What is Red?

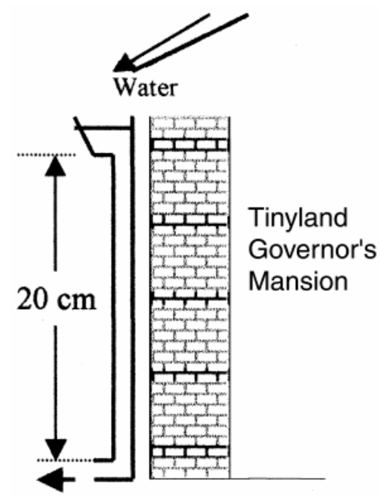

Fig. P6.21

Solution: If the velocity at the gutter surface is neglected, the energy equation reduces to

$$\Delta z = \frac{V^2}{2g} + h_f, \quad \text{where } h_{f,\text{laminar}} = \frac{32\mu LV}{\rho g d^2}$$

For water, take ρ = 998 kg/m^3 and μ = 0.001 kg/m·s. (a) With Δz known, this is a quadratic equation for the pipe velocity V:

$$0.2\ m = \frac{V^2}{2(9.81\ m/s^2)} + \frac{32(0.001\ kg/m{\cdot}s)(0.2\ m)V}{(998\ kg/m^3)(9.81\ m/s^2)(0.002\ m)^2},$$

$$\text{or:} \quad 0.051V^2 + 0.1634V - 0.2 = 0, \quad \textit{Solve for } V = 0.945\ \frac{m}{s},$$

$$Q = \frac{\pi}{4}(0.002\ m)^2\left(0.945\ \frac{m}{s}\right) = 2.97E\text{–}6\ \frac{m^3}{s} = \mathbf{0.0107}\ \frac{\mathbf{m^3}}{\mathbf{h}} \quad \textit{Ans.}\text{ (a)}$$

(b) The roof area needed for maximum rainfall is 0.0107 m^3/h ÷ 0.005 m/h = **2.14 m^2**. *Ans.* (b)
(c) The Reynolds number of the gutter is Red = (998)(0.945)(0.002)/(0.001) = **1890** *laminar*. *Ans.* (c)