6.81 The pump in Fig. P6.80 is used to deliver gasoline at 20°C through 350 m of 30-cm-diameter galvanized iron pipe. Estimate the resulting flow rate, in m^3/s. (Note that the pump head is now in meters of gasoline.)

Solution: For gasoline, take ρ = 680 kg/m³ and μ = 2.92E–4 kg/m·s. For galvanized iron, take $\varepsilon \approx$ 0.15 mm, hence ε/d = 0.15/300 ≈ 0.0005. Head loss matches pump head:

$$h_f = \frac{8fLQ^2}{\pi^2 g d^5} = \frac{8f(350)Q^2}{\pi^2(9.81)(0.3)^5} = 11901fQ^2 = h_{pump} \approx 80 - 20Q^2, \quad Q^2 = \frac{80}{20 + 11901f}$$

$$\text{Guess} \quad f_{rough} \approx 0.017, \quad Q \approx 0.600 \ \frac{m^3}{s},$$

$$Re_{better} \approx 5.93E6, \quad \frac{\varepsilon}{d} = 0.0005, \quad f_{better} \approx 0.0168$$

This converges to $f \approx 0.0168$, $Re \approx 5.96E6$, $\mathbf{Q \approx 0.603\ m^3/s}$. *Ans.*

6.82 The pump in Fig. P6.80 has its maximum efficiency at a head of 45 m. If it is used to pump ethanol at 20°C through 200 m of commercial-steel pipe, what is the proper pipe diameter for maximum pump efficiency?

Solution: For ethanol, take ρ = 789 kg/m³ and μ = 1.2E−3 kg/m·s. For commercial steel, take $\varepsilon \approx$ 0.046 mm, hence $\varepsilon/d = 0.046/(1000d)$. We know the head and flow rate:

$$h_{pump} = 45 \text{ m} \approx 80 - 20Q^2, \quad \text{solve for } Q \approx 1.323 \text{ m}^3/\text{s}.$$

$$\text{Then} \quad h_p = h_f = \frac{8fLQ^2}{\pi^2 g d^5} = \frac{8f(200)(1.323)^2}{\pi^2(9.81)d^5} = \frac{28.92f}{d^5} = 45 \text{ m}, \quad \text{or:} \quad d \approx 0.915f^{1/5}$$

$$\text{Guess} \quad f \approx 0.02, \quad d \approx 0.915(0.02)^{1/5} \approx 0.419 \text{ m},$$

$$Re = \frac{4\rho Q}{\pi\mu d} \approx 2.6E6, \quad \frac{\varepsilon}{d} \approx 0.000110$$

$$\text{Then} \quad f_{better} \approx 0.0130, \quad d_{better} \approx 0.384 \text{ m}, \quad Re_{better} \approx 2.89E6, \quad \frac{\varepsilon}{d}\Big|_{better} \approx 0.000120$$

This converges to $f \approx 0.0129$, $Re \approx 2.89E6$, $\mathbf{d \approx 0.384\ m}$. *Ans.*
