Solution: For water at 20°C, take $\rho = 998$ kg/m^3 and $\mu = 0.001$ kg/m·s. For galvanized iron, take $\varepsilon \approx 0.15$ mm, hence $\varepsilon/d = 0.003$. First establish minor losses as shown:

$$\text{Protruding entrance (Fig. 6.21a),} \quad \frac{L}{d} \approx 1.2,\ K \approx 1;$$

$$\text{Butterfly @ 30° (Fig 6.19)} \quad K \approx 80 \pm 20$$

The energy equation, with $p_1 = p_2$, yields:

$$\Delta z = \frac{V^2}{2g} + h_f + \sum h_m = \frac{V^2}{2g}\left[1 + f\frac{L}{d} + \sum K\right] = \frac{V^2}{2(9.81)}\left[1 + f\left(\frac{2}{0.05}\right) + 1.0 + 80 \pm 20\right] = 5\text{ m}$$

$$\text{Guess} \quad f \approx 0.02, \quad V \approx 1.09\ \frac{m}{s}, \quad Re \approx 54300, \quad \frac{\varepsilon}{d} = 0.003,$$

$$f_{new} \approx 0.0284, \quad V_{new} \approx 1.086\ \frac{m}{s}$$

Thus the "base" flow, for our comparison, is $V_o \approx 1.086$ m/s, $Q_o \approx 0.00213$ m^3/s.
If we cut off the entrance flush, we reduce K_{ent} from 1.0 to **<u>0.5</u>**; hardly a significant reduction in view of the huge butterfly valve loss $K_{valve} \approx 80$. The energy equation is

$$5\text{ m} = \frac{V^2}{2(9.81)}[1 + 40f + 0.5 + 80 \pm 20], \quad \text{solve } V \approx 1.090\ \frac{m}{s},$$

$$Q = \mathbf{0.00214\ \frac{m^3}{s}} \quad (0.3\%\text{ more}) \quad \textit{Ans. (a)}$$

If we open the butterfly wide, K_{valve} decreases from 80 to only **<u>0.3</u>**, a *huge* reduction:

$$5\text{ m} = \frac{V^2}{2(9.81)}[1 + 40f + 1.0 + 0.3], \quad \text{solve } V \approx 5.4\ \frac{m}{s},$$

$$Q = \mathbf{0.0106\ \frac{m^3}{s}} \quad (5\text{ times more}) \quad \textit{Ans. (b)}$$

Obviously opening the valve has a dominant effect for this system.

6.108 The water pump in Fig. P6.108 maintains a pressure of 6.5 psig at point 1. There is a filter, a half-open disk valve, and two regular screwed elbows. There are 80 ft of 4-inch diameter commercial steel pipe. (a) If the flow rate is 0.4 ft^3/s, what is the loss coefficient of the filter? (b) If the disk valve is wide open and $K_{filter} = 7$, what is the resulting flow rate?