Example Water at 25°C flows through a 5 cm diameter pipe at $3.5\times10^{-3}\ m^3/s$. Assuming that the inlet of the pipe is connected to a large reservoir, estimate the entrance length. Are entrance effects likely to be significant if the pipe is 100 m long?

Solution Strategy (1) compute Re_D
(2) use appropriate entrance length correlation to compute Le_D

At 25°C, $\nu = 9.03\times10^{-7}\ m^2/s$ (Interpolate in Table B.2 p. 853 in MYO)

$$Q = 3.5\times10^{-3}\ m^3/s$$

$$V = \frac{Q}{A} = \frac{3.5\times10^{-3}\ m^3/s}{\frac{\pi}{4}\left(5\times10^{-2}\ m\right)^2} = 1.78\ m/s$$

$$Re_D = \frac{VD}{\nu} = \frac{\left(1.78\ m/s\right)\left(5\times10^{-2}\ m\right)}{\left(9.03\times10^{-7}\ m^2/s\right)} = 9.87\times10^{4}$$

$Re_D > 2000$, therefore flow is turbulent

Use equation 8.2, p. 464 to estimate Le

$$\frac{Le}{D} = 4.4\,Re_D^{1/6} = (4.4)\left(9.87\times10^{4}\right)^{1/6} = 30$$

$$Le = 30\,D = 150\ cm = 1.5\ m$$

For this flow rate the entrance length only occupies 1.5% of a 100 m pipe. Entrance effects are not likely to be significant.

Example A 3 inch diameter commercial steel pipe, 10000 ft long carries water at $0.116\ ft^3/s$.

(a) Compute the head loss neglecting any minor losses

(b) Compute the total head loss with the addition of
- a sharp-edged reservoir entrance
- a sharp-edged discharge into downstream reservoir
- a wide open globe valve
- four 90° elbows, threaded.

(a) Head loss in pipe, neglecting minor losses

$$Q = 0.116\ ft^3/s, \quad D = 3\ in \Rightarrow V = \frac{Q}{A} = \frac{0.116\ ft^3/s}{\frac{\pi}{4}\left(\frac{3}{12} ft\right)^2}$$

$$V = 2.36\ ft/s$$

No temperature given, assume std conditions

From Table 1.6 $\quad \rho = 1.94 \frac{slugs}{ft^3}, \quad \mu = 2.34 \times 10^{-5} \frac{lb_f \cdot s}{ft^2} \left(\frac{slug}{ft \cdot s}\right)$

$$\frac{lb_f \cdot s}{ft^2} = \frac{slug\frac{ft}{s^2} \cdot s}{ft^2} = \frac{slug}{ft \cdot s}$$

$$Re = \frac{\rho V D}{\mu} = \frac{\left(1.94 \frac{slug}{ft^3}\right)\left(2.36\ ft/s\right)\left(\frac{3}{12} ft\right)}{2.34 \times 10^{-5} \frac{slug}{ft \cdot s}} = 48{,}910$$

$\therefore$ flow is turbulent

Commercial steel pipe, Table 8.1, p. 492 $\quad \varepsilon = 0.00015\ ft$

$$\frac{\varepsilon}{D} = \frac{0.00015\ ft}{3/12\ ft} = 6 \times 10^{-4}$$

Colebrook equation: $\quad f = f\left(\frac{\varepsilon}{D}, Re\right) = f\left(6\times10^{-4}, 48{,}910\right)$

$$f = 0.023$$

Compute head loss from Darcy-Weisbach

$$h_L = f \frac{L}{D} \frac{V^2}{2g}$$

$$= (0.023)\left(\frac{10{,}000 \text{ ft}}{3/12 \text{ ft}}\right)\left(\frac{(2.36 \text{ ft/s})^2}{(2)(32.2 \text{ ft/s}^2)}\right)$$

$$h_L = 79.6 \text{ ft}$$

(b) Minor Losses $h_L = K_L \frac{V^2}{2g}$

Reservoir entrance	$K_L = 0.5$	Fig 8.22	p. 498
Reservoir exit	$K_L = 1.0$	Fig. 8.25	p. 499
Globe Valve fully open	$K_L = 10$	Table 8.2	p. 505
90° elbows threaded	$K_L = 1.5$	Table 8.2	p. 505

Total minor loss

$$\Sigma h_{L,\text{minor}} = \left[\underbrace{0.5 + 1.0 + 10 + 4(1.5)}_{17.5}\right]\frac{(2.36 \text{ ft/s})^2}{(2)(32.2 \text{ ft/s}^2)}$$

$$= 1.5 \text{ ft}$$

In this example minor losses are $\frac{1.5}{79.6+1.5} \simeq 2$ percent