8.7. For laminar flow in a pipe or system with a similar flow geometry, flow is laminar at Reynolds numbers \(<2100\). At 10°C, the kinematic viscosity ($\nu$) of water is $1.31 \times 10^{-6} \text{ m}^2/\text{s}$ (from Table B.2, p.761). The velocity of the fluid is:

$$V = \frac{Q}{A} = \frac{\left(4 \text{ cm}^3/\text{s}\right)}{\pi \left(0.4 \text{ cm}\right)^2 / 4} = 31.8 \text{ cm/s}$$

The Reynolds number is therefore:

$$\text{Re} = \frac{DV}{\nu} = \frac{(0.4 \text{ cm})(31.8 \text{ cm/s})}{(1.31\times10^{-6} \text{ m}^2/\text{s})(100 \text{ cm/m})^2} = 971$$

The flow is laminar. For laminar flow, the ratio of the entrance length to the diameter is given by:

$$\frac{l_e}{D} = 0.06 \text{Re} = 0.06(971) = 58.3$$

$$l_e = 58.3D = 58.3(0.4 \text{ cm}) = 23.3 \text{ cm}$$

Since the straw length (25 cm) is longer than $l_e$, the flow is fully developed.

8.15. The maximum pressure is the pressure that causes the Reynolds number to equal 2100. Thus:

$$\text{Re} = 2100 = \frac{DV}{\mu}$$

$$V = \frac{2100\mu}{D\rho} = \frac{2100(0.30 \text{ N-s/m}^2)}{(0.1 \text{ m})(10^3 \text{ kg/m}^3)\left(1 \frac{\text{N}}{\text{kg-m/s}^2}\right)} = 6.3 \text{ m/s}$$

For laminar flow, the headloss and pressure change due to friction are given by the Hagen-Poiseuille equation. If, in addition to friction, pressure changes because of a change in elevation, the overall pressure change is given by Equation 8.11 or 8.12. Using Equation 8.11, we find:

$$V = \frac{(\Delta p - \gamma l \sin \theta)D^2}{32\mu l}$$
\[ \Delta p = \frac{32 \mu l V}{D^2} + \gamma l \sin \theta = \frac{32 \left(0.30 \text{ N-s/m}^2\right)(10 \text{ m})(6.3 \text{ m/s})}{(0.10 \text{ m})^2} + \left(9810 \frac{\text{N}}{\text{m}^3}\right)(10 \text{ m})\sin(-90^\circ) \]

\[ = -37,620 \text{ Pa} = -37.6 \text{ kPa} \]

8.19. The velocity profile for laminar flow in a pipe is given by:

\[ V = V_c \left(1 - \left[\frac{r}{R}\right]^2\right) \]

where \( V_c \) is the centerline velocity, \( r \) is the distance measured from the centerline, and \( R \) is the pipe radius. In the current case, \( R = 0.05 \text{ cm} \), \( r = (0.050 - 0.012) \text{ cm} \), or 0.038 cm, and \( V = 0.8 \text{ m/s} \). Also, the average velocity for laminar flow in a pipe is one-half of the maximum (centerline) velocity. The centerline velocity and flow are therefore:

\[ V_c = \frac{V}{1 - \left(\frac{r}{R}\right)^2} = \frac{0.8 \text{ m/s}}{1 - \left(\frac{0.038}{0.05}\right)^2} = 1.89 \text{ m/s} \]

\[ Q = V_{avg} A = 0.5V_c A = (0.5)(1.89 \text{ m/s})(\pi(0.05 \text{ m})^2) = 7.42 \times 10^{-3} \text{ m}^3/\text{s} \]

8.21. The Darcy-Weisbach equation applies for either laminar or turbulent flow. Thus, for either case of interest:

\[ h_L = f \frac{l V^2}{D 2g} \]

Since \( l, D, V \) and \( g \) are the same for the two cases, the ratio of the headloss in laminar to turbulent flow is the ratio of the corresponding friction factors. For laminar flow, \( f = 64/\text{Re} \); for \( \text{Re} = 6000, f = 0.0107 \). For turbulent flow with a smooth pipe, we can find the friction factor from the Moody diagram, with the result that, for \( \epsilon/D = 0 \) and \( \text{Re} = 6000, f = 0.035 \). Therefore, if the flow were laminar, the headloss would be reduced by:

\[ \frac{0.035 - 0.0107}{0.035} = 0.694 = 69.4\% \]