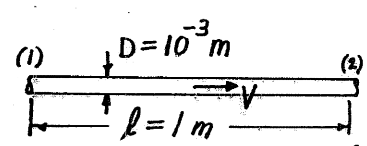
8.16

8.16 Water at 20 °C flows through a horizontal 1-mm-diameter tube to which are attached two pressure taps a distance 1 m apart. **(a)** What is the maximum pressure drop allowed if the flow is to be laminar? **(b)** Assume the manufacturing tolerance on the tube diameter is $D = 1.0 \pm 0.1$ mm. Given this uncertainty in the tube diameter, what is the maximum pressure drop allowed if it must be assured that the flow is laminar?



From Table B.2 $\nu = 1.00 \times 10^{-6} \frac{m^2}{s}$
$\mu = 1.00 \times 10^{-3} \frac{N \cdot s}{m^2}$

a) Maximum Δp corresponds to maximum V, or

$$Re = \frac{VD}{\nu} = 2100$$

Thus, $$V = \frac{2100\,\nu}{D} = \frac{2100(1 \times 10^{-6} \frac{m^2}{s})}{10^{-3}\,m} = 2.10 \frac{m}{s}$$

For laminar flow

$$V = \frac{\Delta p\, D^2}{32 \mu \ell}, \text{ or } \Delta p = \frac{32 \mu \ell V}{D^2} = \frac{32(1 \times 10^{-3} \frac{N \cdot s}{m^2})(1m)(2.10 \frac{m}{s})}{(10^{-3}m)^2}$$

Thus,

$$\Delta p = 6.72 \times 10^4 \frac{N}{m^2}$$

b) Since $V = \frac{2100\,\nu}{D}$ and $\Delta p = \frac{32 \mu \ell V}{D^2}$ it follows that

$$\Delta p = \frac{32 \mu \ell (2100 \nu)}{D^3}$$

Thus, the larger the diameter, the smaller the Δp allowed to maintain laminar flow.

Thus, consider $D = 1.1\ mm = 1.1 \times 10^{-3} m$, or

$$\Delta p = \frac{32(1 \times 10^{-3} \frac{N \cdot s}{m^2})(1m)(2100)(1 \times 10^{-6} \frac{m^2}{s})}{(1.1 \times 10^{-3} m)^3} = 5.05 \times 10^4 \frac{N}{m^2}$$