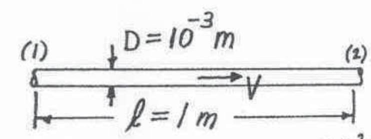
8.17

8.17 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, $$V = \frac{2100\,\nu}{D} = \frac{2100\left(1\times10^{-6}\frac{m^2}{s}\right)}{10^{-3}\,m} = 2.10\,\frac{m}{s}$$

For laminar flow

$$V = \frac{\Delta p\, D^2}{32\mu\ell}\,, \text{ or } \Delta p = \frac{32\mu\ell V}{D^2} = \frac{32\left(1\times10^{-3}\frac{N\cdot s}{m^2}\right)(1m)\left(2.10\frac{m}{s}\right)}{\left(10^{-3}m\right)^2}$$

Thus,

$$\underline{\underline{\Delta p = 6.72\times10^{4}\,\frac{N}{m^2}}}$$

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 $D = 1.1\ mm = 1.1\times10^{-3} m$, or

$$\Delta p = \frac{32\left(1\times10^{-3}\frac{N\cdot s}{m^2}\right)(1m)(2100)\left(1\times10^{-6}\frac{m^2}{s}\right)}{\left(1.1\times10^{-3}m\right)^3} = \underline{\underline{5.05\times10^{4}\,\frac{N}{m^2}}}$$