$$\text{Guessing}\quad \rho_{oil} \approx 900\ \frac{kg}{m^3},$$

$$\text{check}\ \ Re = \frac{4\rho Q}{\pi\mu d} = \frac{4(900)(0.071/3600)}{\pi(0.292)(0.005)} \approx \mathbf{16}\quad \textbf{OK, laminar}\quad \textit{Ans.}$$

It is not possible to find density from this data, laminar pipe flow is independent of density.

6.13 A soda straw is 20 cm long and 2 mm in diameter. It delivers cold cola, approximated as water at 10°C, at a rate of 3 cm^3/s. (a) What is the head loss through the straw? What is the axial pressure gradient $\partial p/\partial x$ if the flow is (b) vertically up or (c) horizontal? Can the human lung deliver this much flow?

Solution: For water at 10°C, take ρ = 1000 kg/m^3 and μ = 1.307E−3 kg/m·s. Check Re:

$$Re = \frac{4\rho Q}{\pi\mu d} = \frac{4(1000)(3E\text{–}6\ m^3/s)}{\pi(1.307E\text{–}3)(0.002)} = 1460\quad \text{(OK, laminar flow)}$$

$$\text{Then, from Eq. (6.12),}\quad h_f = \frac{128\mu LQ}{\pi\rho g d^4} = \frac{128(1.307E\text{–}3)(0.2)(3E\text{–}6)}{\pi(1000)(9.81)(0.002)^4} \approx \mathbf{0.204\ m}\quad \textit{Ans. (a)}$$

If the straw is *horizontal*, then the pressure gradient is simply due to the head loss:

$$\frac{\Delta p}{L}\Big|_{horiz} = \frac{\rho g h_f}{L} = \frac{1000(9.81)(0.204\ m)}{0.2\ m} \approx \mathbf{9980\ \frac{Pa}{m}}\quad \textit{Ans. (c)}$$

If the straw is *vertical*, with flow *up*, the head loss and elevation change add together:

$$\frac{\Delta p}{L}\Big|_{vertical} = \frac{\rho g(h_f + \Delta z)}{L} = \frac{1000(9.81)(0.204 + 0.2)}{0.2} \approx \mathbf{19800\ \frac{Pa}{m}}\quad \textit{Ans. (b)}$$

The human lung can certainly deliver case (c) and strong lungs can develop case (b) also.
