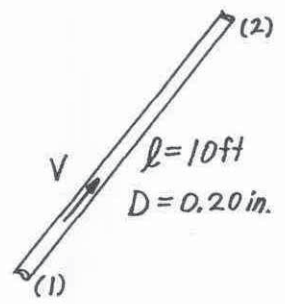
8.49

8.49 Blood (assume $\mu = 4.5 \times 10^{-5}$ lb·s/ft², $SG = 1.0$) flows through an artery in the neck of a giraffe from its heart to its head at a rate of 2.5×10^{-4} ft³/s. Assume the length is 10 ft and the diameter is 0.20 in. If the pressure at the beginning of the artery (outlet of the heart) is equivalent to 0.70 ft Hg, determine the pressure at the end of the artery when the head is **(a)** 8 ft above the heart, or **(b)** 6 ft below the heart. Assume steady flow. How much of this pressure difference is due to elevation effects, and how much is due to frictional effects?



$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + f\frac{\ell}{D}\frac{V^2}{2g}$, where $V_1 = V_2 = V$ (1)

and

$V = \frac{Q}{A} = \frac{2.5\times10^{-4}\ \frac{ft^3}{s}}{\frac{\pi}{4}\left(\frac{0.2}{12}ft\right)^2} = 1.146\ \frac{ft}{s}$ Thus, $Re = \frac{\rho VD}{\mu}$, or

$Re = \frac{(1.94\ \frac{slugs}{s})(1.146\ \frac{ft}{s})(\frac{0.2}{12}ft)}{4.5\times10^{-5}\ \frac{lb\cdot s}{ft^2}} = 823$ Hence, the flow is laminar with

$f = \frac{64}{Re} = \frac{64}{823} = 0.0778$

Also, $p_1 = \gamma_{Hg} h = (847\ \frac{lb}{ft^3})(0.70ft) = 593\ \frac{lb}{ft^2}$

Hence, from Eq. (1)

$p_2 = p_1 - \gamma(z_2 - z_1) - f\frac{\ell}{D}\frac{1}{2}\rho V^2$

a) With $z_2 - z_1 = 8ft$,

$p_2 = 593\ \frac{lb}{ft^2} - (62.4\ \frac{lb}{ft^3})(8ft) - 0.0778\ \frac{10ft}{(\frac{0.2}{12}ft)}\ (\frac{1}{2})(1.94\ \frac{slugs}{ft^3})(1.146\ \frac{ft}{s})^2$

$= 593\ \frac{lb}{ft^2} - 499\ \frac{lb}{ft^2} - 59.5\ \frac{lb}{ft^2} = \underline{\underline{34.5\ \frac{lb}{ft^2}}}$

Note: $-499\ \frac{lb}{ft^2}$ is due to elevation, -59.5 is due to friction.

b) With $z_2 - z_1 = -6ft$,

$p_2 = 593\ \frac{lb}{ft^2} - (62.4\ \frac{lb}{ft^3})(-6ft) - 0.0778\ \frac{10ft}{(\frac{0.2}{12}ft)}\ (\frac{1}{2})(1.94\ \frac{slugs}{ft^3})(1.146\ \frac{ft}{s})^2$

$= 593\ \frac{lb}{ft^2} + 374\ \frac{lb}{ft^2} - 59.5\ \frac{lb}{ft^2} = \underline{\underline{908\ \frac{lb}{ft^2}}}$

Note: $374\ \frac{lb}{ft^2}$ is due to elevation, $-59.5\ \frac{lb}{ft}$ is due to friction.