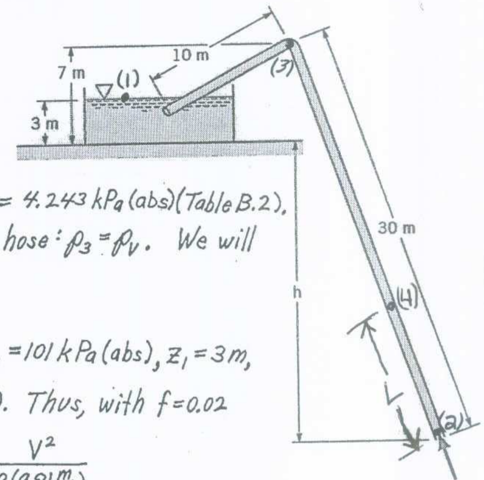
8.53

8.53 A 40-m-long, 12-mm-diameter pipe with a friction factor of 0.020 is used to siphon 30 °C water from a tank as shown in Fig. P8.53. Determine the maximum value of h allowed if there is to be no cavitation within the hose. Neglect minor losses.



The minimum pressure is the vapor pressure $p_v = 4.243\ kPa\ (abs)$ (Table B.2). Assume the minimum pressure is at the top of the hose: $p_3 = p_v$. We will check this assumption after we obtain h.

Thus,

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_3}{\gamma} + \frac{V_3^2}{2g} + z_3 + f\frac{\ell}{D}\frac{V^2}{2g}, \text{ where } p_1 = 101\ kPa\ (abs),\ z_1 = 3m,$$

$z_3 = 7m$, $V_1 = 0$, $V_3 = V$, and $p_3 = 4.243\ kPa(abs)$. Thus, with $f = 0.02$

$$\frac{(101-4.243)\frac{kN}{m^2}}{9.77\frac{kN}{m^3}} + 3\,m = 7\,m + \left(1 + 0.02\left(\frac{10m}{0.012m}\right)\right)\frac{V^2}{2(9.81\frac{m}{s^2})}$$

or

$V = 2.56\frac{m}{s}$.

Obtain h from

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + f\frac{\ell}{D}\frac{V^2}{2g}, \text{ where } p_2 = 0,\ V_2 = V = 2.56\frac{m}{s},$$

$z_2 = -h$, and $\ell = 40m$. That is, with $p_1 = p_2 = 0$

$$3\,m = -h + \left(1 + 0.02\left(\frac{40m}{0.012m}\right)\right)\frac{(2.56\frac{m}{s})^2}{2(9.81\frac{m}{s^2})}, \text{ or } h = \underline{\underline{19.6\,m}}$$

Check if minimum pressure occurs at (3). Consider point (4).

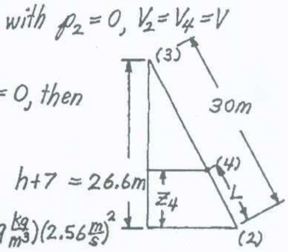
From $\frac{p_4}{\gamma} + \frac{V_4^2}{2g} + z_4 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + f\frac{L}{D}\frac{V^2}{2g}$ with $p_2 = 0$, $V_2 = V_4 = V$

we obtain

$p_4 = \gamma(z_2 - z_4) + f\frac{L}{D}\frac{1}{2}\rho V^2$ If we use $z_2 = 0$, then

from the figure: $\frac{L}{z_4} = \frac{30}{26.6}$, or $L = 1.128 z_4$

Thus,



$$p_4 = 9.80\frac{kN}{m^3}(-z_4) + (0.02)\left(\frac{1.128 z_4}{0.012}\right)\left(\tfrac{1}{2}\right)\left(999\tfrac{kg}{m^3}\right)\left(2.56\tfrac{m}{s}\right)^2$$

or

$$p_4 = (-9.80\times10^3 + 6.15\times10^3)\,z_4 = -3650\,z_4$$

Thus, p_4 decreases as z_4 increases. That is, the minimum pressure occurs at section (3) as assumed.