Solution: (a) Assume no pressure drop and neglect velocity heads. The energy equation reduces to:

$$\frac{p_1}{\rho g}+\frac{V_1^2}{2g}+z_1=0+0+(L+l)=\frac{p_2}{\rho g}+\frac{V_2^2}{2g}+z_2+h_f=0+0+0+h_f,\quad \textbf{\textit{or}}:\quad h_f\approx L+l$$

$$\textit{For laminar flow,}\quad h_f=\frac{128\mu LQ}{\pi\rho g d^4}\quad \textit{and, for uniform draining,}\; Q=\frac{\upsilon}{\Delta t}$$

$$\textit{Solve for}\quad \boldsymbol{\Delta t=\frac{128\mu L\upsilon}{\pi\rho g d^4(L+l)}}\quad \textit{Ans.}\text{ (a)}$$

(b) Apply to $\Delta t = 6$ s. For water, take $\rho = 998$ kg/m^3 and $\mu = 0.001$ kg/m·s. Formula (a) predicts:

$$\Delta t=6\ s=\frac{128(0.001\ kg/m{\cdot}s)(0.12\ m)(8E\text{–}6\ m^3)}{\pi(998\ kg/m^3)(9.81\ m/s^2)d^4(0.12+0.02\ m)},$$

Solve for **d ≈ 0.0015 m** *Ans.* (b)

6.18 To determine the viscosity of a liquid of specific gravity 0.95, you fill, to a depth of 12 cm, a large container which drains through a 30-cm-long vertical tube attached to the bottom. The tube diameter is 2 mm, and the rate of draining is found to be 1.9 cm^3/s. What is your estimate of the fluid viscosity? Is the tube flow laminar?

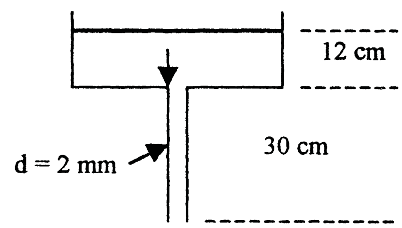

Fig. P6.18

Solution: The known flow rate and diameter enable us to find the velocity in the tube:

$$V=\frac{Q}{A}=\frac{1.9E\text{–}6\ m^3/s}{(\pi/4)(0.002\ m)^2}=0.605\ \frac{m}{s}$$

Evaluate $\rho_{\text{liquid}} = 0.95(998) = 948$ kg/m^3. Write the energy equation between the top surface and the tube exit:

$$\cancel{\frac{p_a}{\rho g}}+\cancel{\frac{V_{top}^2}{2g}}+z_{top}=\cancel{\frac{p_a}{\rho g}}+\frac{V^2}{2g}+0+h_f,$$

$$or:\quad 0.42=\frac{V^2}{2g}+\frac{32\mu LV}{\rho g d^2}=\frac{(0.605)^2}{2(9.81)}+\frac{32\mu(0.3)(0.605)}{948(9.81)(0.002)^2}$$