Solution: (a) Write the steady flow energy equation from top to bottom:

$$\cancel{\frac{p_1}{\rho g}}+\cancel{\frac{\alpha_1 V_1^2}{2g}}+(H+L)=\cancel{\frac{p_2}{\rho g}}+\frac{\alpha_2 V_2^2}{2g}+0+h_f,\quad or:\quad h_f=\frac{32\mu LV}{\rho g d^2}=H+L-\frac{\alpha_2 V_2^2}{2g}$$

Noting that, in a tube, Q = Vπd^2/4, we may eliminate V in favor of Q and solve for the fluid viscosity:

$$\boldsymbol{\mu=\frac{\pi\rho g d^4}{128LQ}(H+L)-\frac{\alpha_2\rho Q}{16\pi L}}\quad \textit{Ans.}\text{ (a)}$$

(b) For the given data, converting d = 0.041 in = 0.00104 m, L = 36.1 in = 0.917 m, and Q = 0.31 mL/s = 3.1E−7 m^3/s, we may substitute in the above formula (a) and calculate

$$\mu=\frac{\pi(998.7)(9.81)(0.00104)^4}{128(0.917)(3.1E\text{–}7)}(0.153+0.917)-\frac{2.0(998.7)(3.1E\text{–}7)}{16\pi(0.917)}$$

$$=0.001063-0.000013\approx \mathbf{0.00105}\ \frac{\mathbf{kg}}{\mathbf{m\cdot s}}\quad \textit{Ans.}\text{ (b)}$$

(c) The accepted value (see Appendix Table A-1) for water at 16.5°C is $\mu \approx$ 1.11E−3 kg/m·s, the error in the experiment is thus about **−5.5%**. *Ans.* (c)
(d) If we forgot the kinetic-energy correction factor $\alpha 2$ = 2.0 for laminar flow, the calculation in part (b) above would result in

$$\mu=0.001063-0.000007\approx \mathbf{0.001056\ kg/m\cdot s}\ \text{(negligible 0.6\% error)}\quad \textit{Ans.}\text{ (d)}$$

In this experiment, the dominant (first) term is the *elevation change* (H + L)—the momentum exiting the tube is negligible because of the low velocity (0.36 m/s).

3.139 The horizontal pump in Fig. P3.139 discharges 20°C water at 57 m^3/h. Neglecting losses, what power in kW is delivered to the water by the pump?

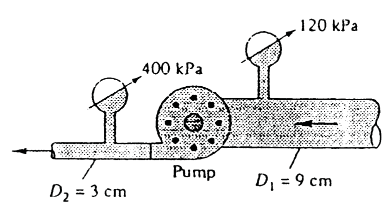

Fig. P3.139

Solution: First we need to compute the velocities at sections (1) and (2):

$$V_1=\frac{Q}{A_1}=\frac{57/3600}{\pi(0.045)^2}=2.49\ \frac{m}{s};\quad V_2=\frac{Q}{A_2}=\frac{57/3600}{\pi(0.015)^2}=22.4\ \frac{m}{s}$$