8.21 Oil of $SG = 0.87$ and a kinematic viscosity $\nu = 2.2 \times 10^{-4}\ m^2/s$ flows through the vertical pipe shown in Fig. P8.25 at a rate of $4 \times 10^{-4}\ m^3/s$. Determine the manometer reading, h.

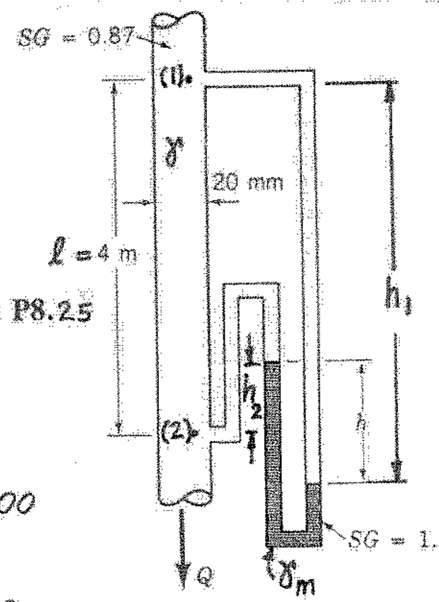

FIGURE P8.25

$$V = \frac{Q}{A} = \frac{4\times10^{-4}\,\frac{m^3}{s}}{\frac{\pi}{4}(0.02\,m)^2} = 1.27\,\frac{m}{s} \quad \text{so that}$$

$$Re = \frac{\rho V D}{\mu} = \frac{VD}{\nu} = \frac{(1.27\,\frac{m}{s})(0.02\,m)}{2.2\times10^{-4}\,\frac{m^2}{s}} = 115 < 2100$$

The flow is laminar with

$$Q = \frac{\pi(\Delta p + \gamma \ell)D^4}{128\,\mu\,\ell}, \quad \text{or} \quad \Delta p = p_1 - p_2 = \frac{128\,\mu\,\ell\,Q}{\pi D^4} - \gamma \ell \qquad (1)$$

Hence, with $\gamma = SG\,\gamma_{H_2O} = 0.87(9.81\,\frac{kN}{m^3}) = 8.53\,\frac{kN}{m^3}$ and

$$\mu = \nu \rho = \nu\, SG\, \rho_{H_2O} = (2.2\times10^{-4}\,\frac{m^2}{s})(0.87)(1000\,\frac{kg}{m^3}) = 0.191\,\frac{N\cdot s}{m^2}$$

Eq. (1) gives

$$\Delta p = \frac{128\,(0.191\,\frac{N\cdot s}{m^2})(4\,m)(4\times10^{-4}\,\frac{m^3}{s})}{\pi\,(0.020\,m)^4} - (8.53\,\frac{kN}{m^3})(4\,m)(10^3\,\frac{N}{kN})$$

or $\Delta p = 4.37\times10^4\,\frac{N}{m^2} = 43.7\,\frac{kN}{m^2}$ (2)

From manometer considerations

$$p_1 + \gamma h_1 - \gamma_m h + \gamma h_2 = p_2, \quad \text{where} \quad \gamma_m = SG_m\,\gamma_{H_2O} = 1.3(9.81\,\frac{kN}{m^3}) = 12.74\,\frac{kN}{m^3}$$

and $h_1 = h - h_2 + \ell$, or $h_2 + h_1 = h + \ell$

Thus,

$$p_1 - p_2 = \Delta p = -\gamma(h_2 + h_1) + \gamma_m h = (\gamma_m - \gamma)h - \gamma \ell \qquad (3)$$

Combine Eqs. (2) and (3) to give

$$43.7\,\frac{kN}{m^2} = (12.74 - 8.53)\frac{kN}{m^3}\,h - (8.53\,\frac{kN}{m^3})(4\,m)$$

or $\underline{h = 18.5\,m}$