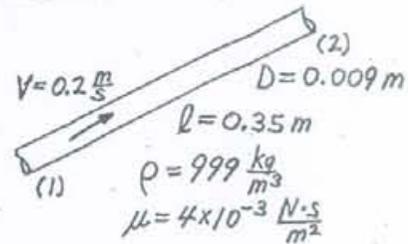


8.22

8.22 A large artery in a person's body can be approximated by a tube of diameter 9 mm and length 0.35 m. Also assume that blood has a viscosity of approximately $4 \times 10^{-3} \text{ N} \cdot \text{s}/\text{m}^2$, a specific gravity of 1.0, and that the pressure at the beginning of the artery is equivalent to 120 mm Hg. If the flow were steady (it is not) with $V = 0.2 \text{ m/s}$, determine the pressure at the end of the artery if it is oriented (a) vertically up (flow up) or (b) horizontal.



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

and

$$p_1 = \rho_{\text{Hg}} h = 133 \frac{\text{kN}}{\text{m}^3} (0.120 \text{ m}) = 15.96 \frac{\text{kN}}{\text{m}^2}$$

$$\text{Also, } Re = \frac{\rho V D}{\mu} = \frac{(999 \frac{\text{kg}}{\text{m}^3})(0.2 \frac{\text{m}}{\text{s}})(0.009 \text{ m})}{4 \times 10^{-3} \frac{\text{N}\cdot\text{s}}{\text{m}^2}} = 450 < 2100 \text{ Thus the flow is laminar so that}$$

$$f = \frac{64}{Re} = \frac{64}{450} = 0.142$$

$$\text{Hence, from Eq. (1), } p_2 = p_1 - \gamma(z_2 - z_1) - f \frac{l}{D} \frac{1}{2} \rho V^2$$

a) For flow vertically up, $z_2 - z_1 = l$ so that

$$p_2 = p_1 - \gamma l - f \frac{l}{D} \frac{1}{2} \rho V^2 = 15.96 \frac{\text{kN}}{\text{m}^2} - (9.81 \times 10^3 \frac{\text{N}}{\text{m}^3})(0.35 \text{ m}) - 0.142 \frac{0.35 \text{ m}}{0.009 \text{ m}} \left(\frac{1}{2}\right) (999 \frac{\text{kg}}{\text{m}^3}) (0.2 \frac{\text{m}}{\text{s}})^2$$

or

$$p_2 = 15.96 \frac{\text{kN}}{\text{m}^2} - 3.43 \frac{\text{kN}}{\text{m}^2} - 0.110 \frac{\text{kN}}{\text{m}^2} = \underline{\underline{12.42 \text{ kPa}}}$$

b) For horizontal flow $z_1 = z_2$ so that

$$p_2 - p_1 = 15.96 \frac{\text{kN}}{\text{m}^2} - 0.142 \frac{0.35 \text{ m}}{0.009 \text{ m}} \left(\frac{1}{2}\right) (999 \frac{\text{kg}}{\text{m}^3}) (0.2 \frac{\text{m}}{\text{s}})^2 = 15.96 \frac{\text{kN}}{\text{m}^2} - 0.110 \frac{\text{kN}}{\text{m}^2} = \underline{\underline{15.85 \text{ kPa}}}$$

Note the gravitational effects are considerably more important than viscous effects (3.43 kPa compared to 0.110 kPa).