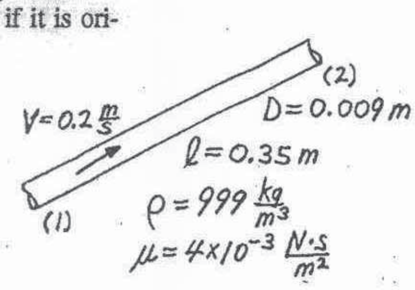
8.19

8.19 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 $4 \times 10^{-3}\ N \cdot s/m^2$, 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 m/s, determine the pressure at the end of the artery if it is oriented (a) vertically up (flow up) or (b) horizontal.



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

and

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

Also, $Re = \frac{\rho V D}{\mu} = \frac{(999\ \frac{kg}{m^3})(0.2\ \frac{m}{s})(0.009\,m)}{4\times10^{-3}\ \frac{N\cdot s}{m^2}} = 450 < 2100$ Thus the flow is laminar so that

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

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

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

$$p_2 = p_1 - \gamma\ell - f\frac{\ell}{D}\frac{1}{2}\rho V^2 = 15.96\ \frac{kN}{m^2} - (9.81\times10^3\ \frac{N}{m^3})(0.35m) - 0.142\ \frac{0.35m}{0.009m}\left(\frac{1}{2}\right)(999\ \frac{kg}{m^3})(0.2\ \frac{m}{s})^2$$

or

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

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

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

$$= 15.96\ \frac{kN}{m^2} - 0.110\ \frac{kN}{m^2} = \underline{\underline{15.85\ kPa}}$$

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