

Hemodynamic Simulator II (P09026)

Circulatory System Analysis

9/25/08

preliminary head loss calculations

heart rate
 $\rightarrow 220 \text{ bpm} \times F_3$

$220 \text{ bpm} \times 1.5 = \frac{330 \text{ L}}{\text{min}} = \frac{10 \text{ m}^3/\text{min}}{60 \text{ s}} = 55 \frac{\text{L}}{\text{s}}$

$\left[\frac{.1818 \frac{\text{L}}{\text{s}}}{.1818} \right]$

$.1818 =$

$1000 \times V_d \approx 90 \text{ ml} \times F_3 = 135 \text{ ml}$

$\frac{135 \text{ ml}}{.1818} = \frac{.135 \text{ L}}{.1818} = .743 \frac{\text{L}}{\text{s}}$

$\left[.743 \frac{\text{L}}{\text{s}} \text{ (max using } F_3 \text{ is } 1.5) \text{ too large?} \right]$

$\left[.33 \frac{\text{L}}{\text{s}} \text{ if use (200 bpm, 90 ml)} \right]$

$\left[.33 \times 2 = .66 \frac{\text{L}}{\text{s}} \text{ slightly more reasonable} \right]$

oxygen most readily available quality

$\left(\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 \right) = \left(\frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 \right) + \sum H_{fr} - \sum H_p$

$140 \text{ mmHg} = 18665 \text{ Pa}$
 $10 \text{ mmHg} = 1333 \text{ Pa}$

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The diagram shows a schematic of a hemodynamic simulator loop. It consists of a horizontal pipe of length $L = 1.0\text{ m}$ and diameter $D = 0.5\text{ cm}$. This pipe is connected to a vertical pipe of height 2.25 m and diameter 0.5 cm . The vertical pipe has a valve at the top. The flow direction is indicated by arrows: from the horizontal pipe into the vertical pipe, and then back down into the horizontal pipe. The pressure at the inlet of the horizontal pipe is P_1 and the pressure at the outlet is P_2 . The flow velocity in the horizontal pipe is V_1 and in the vertical pipe is V_2 . The flow rate is $Q = 66 \frac{\text{L}}{\text{min}}$.

Calculations:

- Flow rate: $Q = 66 \frac{\text{L}}{\text{min}} = \dot{V}$
- Pressures: $P_1 = ?$, $P_2 = 0$, $P_3 = 2.25\text{ cm}$
- Lengths: $L_{\text{hor}} = 1.0\text{ m}$, $L_{\text{ver}} = 2.25\text{ m}$
- Flow rate in m^3/s : $Q = 1.1 \times 10^{-3} \text{ m}^3/\text{s}$
- Velocity in horizontal pipe: $V_1 = 0$
- Velocity in vertical pipe: $V_2 = \frac{Q}{A} = \frac{1.1 \times 10^{-3}}{\frac{\pi}{4} (0.005)^2} = 13 \frac{\text{m}}{\text{s}}$
- Head loss at entrance: $K = 0.5$, $h_{L_e} = K \frac{V_2^2}{2g} = 0.5 \frac{13^2}{2 \times 9.81} = 0.44\text{ m}$
- Head loss in pipe: $h_{L_f} = f \frac{L}{D} \frac{V_2^2}{2g}$, $f = \frac{64}{Re}$
- Reynolds number: $Re = \frac{\rho V D}{\mu} = \frac{1000 \times 13 \times 0.005}{0.01002} = 3269$ (laminar)
- Friction factor: $f = 0.0196$

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$$\sum h_f = \frac{.5 (1.13)^2 \frac{m^3}{s^2}}{2 \cdot 9.8 \frac{m}{s^2}} + \frac{.0196 (1.00) (1.13)^2 \frac{m^3}{s^2}}{(.0354) \frac{m^3}{s^2}}$$

$$\sum h_f = .000431 + .000665$$

$$\sum h_f = .00110 \text{ m}$$

$P_{2a} = 18665 \text{ Pa}$ $P_{2c} = 1852 \text{ Pa}$

$$\frac{P_1}{\rho} = \frac{P_0}{\rho} + \frac{V_0^2}{2} + P_2 + \sum h_f$$

$$\frac{1.01 \times 10^5 \text{ Pa}}{1000 \frac{\text{kg}}{\text{m}^3}} = \frac{18665 \text{ Pa}}{1000 \frac{\text{kg}}{\text{m}^3}} + \frac{(1.13)^2 \frac{m^3}{s^2}}{2 \cdot 1000 \frac{\text{kg}}{\text{m}^3}} + .75 \text{ m} + .00110 \text{ m}$$

$$P_{1a} = 26934 \text{ Pa} \approx 195 \text{ mmHg}$$

$$P_{1c} = 2792.23 \text{ Pa} \approx 20.7 \text{ mmHg}$$