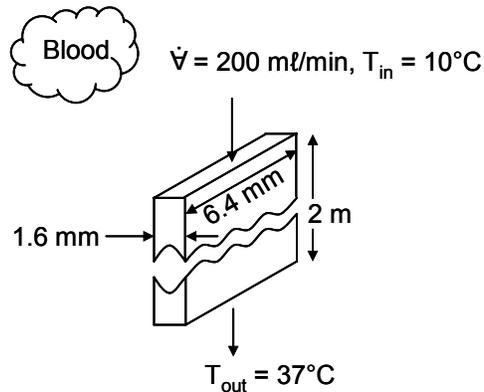


PROBLEM 1.46

KNOWN: Blood inlet and outlet temperatures and flow rate. Dimensions of tubing.

FIND: Required rate of heat addition and estimate of kinetic and potential energy changes.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Incompressible liquid with negligible kinetic and potential energy changes, (3) Blood has properties of water.

PROPERTIES: Table A.6, Water ($\bar{T} \approx 300 \text{ K}$): $c_{p,f} = 4179 \text{ J/kg}\cdot\text{K}$, $\rho_f = 1/v_f = 997 \text{ kg/m}^3$.

ANALYSIS: From an overall energy balance, Equation 1.12e,

$$q = \dot{m}c_p(T_{out} - T_{in})$$

where

$$\dot{m} = \rho_f \dot{V} = 997 \text{ kg/m}^3 \times 200 \text{ ml/min} \times 10^{-6} \text{ m}^3/\text{ml} / 60 \text{ s/min} = 3.32 \times 10^{-3} \text{ kg/s}$$

Thus

$$q = 3.32 \times 10^{-3} \text{ kg/s} \times 4179 \text{ J/kg}\cdot\text{K} \times (37^\circ\text{C} - 10^\circ\text{C}) = 375 \text{ W} \quad <$$

The velocity in the tube is given by

$$V = \dot{V}/A_c = 200 \text{ ml/min} \times 10^{-6} \text{ m}^3/\text{ml} / (60 \text{ s/min} \times 6.4 \times 10^{-3} \text{ m} \times 1.6 \times 10^{-3} \text{ m}) = 0.33 \text{ m/s}$$

The change in kinetic energy is

$$\dot{m}\left(\frac{1}{2}V^2 - 0\right) = 3.32 \times 10^{-3} \text{ kg/s} \times \frac{1}{2} \times (0.33 \text{ m/s})^2 = 1.8 \times 10^{-4} \text{ W} \quad <$$

The change in potential energy is

$$\dot{m}gz = 3.32 \times 10^{-3} \text{ kg/s} \times 9.8 \text{ m/s}^2 \times 2 \text{ m} = 0.065 \text{ W} \quad <$$

COMMENT: The kinetic and potential energy changes are both negligible relative to the thermal energy change.