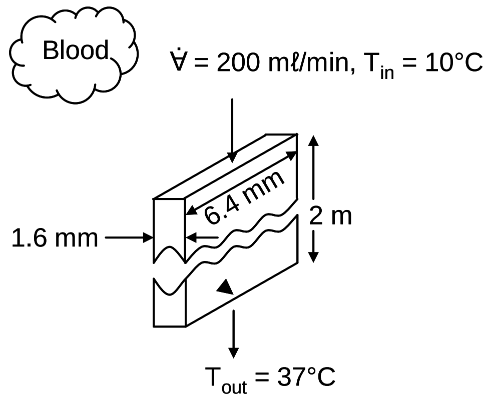
PROBLEM 1.41

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 ($\overline{T} \approx 300$ K): $c_{p,f} = 4179$ J/ kg· K, $\rho_f = 1/v_f = 997$ kg/m^3.

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

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

where

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

Thus

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

The velocity in the tube is given by

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

The change in kinetic energy is

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

The change in potential energy is

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

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