

Problem 2.87

[Difficulty: 2]

2.87 What is the Reynolds number of water at 20°C flowing at 0.25 m/s through a 5-mm-diameter tube? If the pipe is now heated, at what mean water temperature will the flow transition to turbulence? Assume the velocity of the flow remains constant.

Given: Data on water tube

Find: Reynolds number of flow; Temperature at which flow becomes turbulent

Solution:

Basic equation For pipe flow (Section 2-6)
$$\text{Re} = \frac{\rho \cdot V \cdot D}{\mu} = \frac{V \cdot D}{\nu}$$

At 20°C, from Fig. A.3 $\nu = 9 \times 10^{-7} \cdot \frac{\text{m}^2}{\text{s}}$ and so
$$\text{Re} = 0.25 \cdot \frac{\text{m}}{\text{s}} \times 0.005 \cdot \text{m} \times \frac{1}{9 \times 10^{-7} \cdot \frac{\text{m}^2}{\text{s}}} \cdot \frac{\text{s}}{\text{m}^2} \quad \text{Re} = 1389$$

For the heated pipe
$$\text{Re} = \frac{V \cdot D}{\nu} = 2300$$
 for transition to turbulence

Hence
$$\nu = \frac{V \cdot D}{2300} = \frac{1}{2300} \times 0.25 \cdot \frac{\text{m}}{\text{s}} \times 0.005 \cdot \text{m} \quad \nu = 5.435 \times 10^{-7} \frac{\text{m}^2}{\text{s}}$$

From Fig. A.3, the temperature of water at this viscosity is approximately $T = 52^\circ\text{C}$