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Chapter 10, Problem 41P

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Problem

Nutrients dissolved in water are carried to upper parts of plants by tiny tubes partly because of the capillary effect. Determine how high the water solution will rise in a tree in a 0.002-mm-diameter tube as a result of the capillary effect. Treat the solution as water at 20°C with a contact angle of 15°.

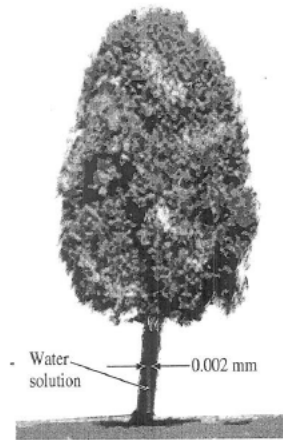


FIGURE P10-41

Step-by-step solution

Step 1 of 2

Given data:

Tube diameter, $D = 0.002$ mm

Contact angle, $\phi = 15^\circ$

Density of water, $\rho = 998.21$ kg/m³

Surface tension of water at 20°C, $\sigma_s = 0.073$ N/m

Radius of capillary tube, $R = \frac{D}{2}$

$$\begin{aligned}
 &= \frac{0.002}{2} \\
 &= 0.001 \text{ mm} \\
 &= 1 \times 10^{-6} \text{ m}
 \end{aligned}$$

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Step 2 of 2

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$$\begin{aligned}
 h &= \frac{\gamma}{\rho g R} \cos \phi \\
 &= \frac{2(0.073 \text{ N/m})}{(998.21 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(1 \times 10^{-6} \text{ m})} \cos 15^\circ \\
 &= 14.4 \text{ m}
 \end{aligned}$$

Therefore the capillary rise is $h = 14.4 \text{ m}$.

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