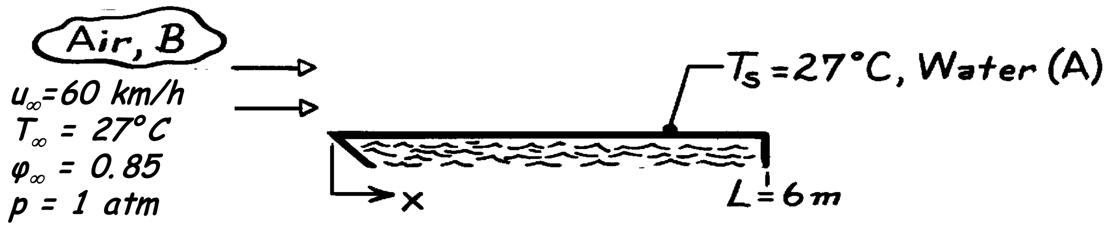
PROBLEM 7.95

KNOWN: Convection mass transfer with turbulent flow over a flat plate (van roof).

FIND: (a) Location on van that will dry last, (b) Evaporation rate at trailing edge, $kg/s \cdot m^2$.

SCHEMATIC:



ASSUMPTIONS: (1) Turbulent flow over entire plate (van top), (2) Heat-mass transfer analogy is applicable, (3) Ideal gas behavior for water vapor (A).

PROPERTIES: *Table A-4*, Air (300 K, 1 atm): $\nu = 15.89 \times 10^{-6}$ m^2/s, k = 0.0263 W/m·K, Pr = 0.707; *Table A-8*, Air-water vapor (25°C): $D_{AB} = 0.26 \times 10^{-4}$ m^2/s; *Table A-6*, Saturated water vapor (300K): $\rho_{A,sat} = v_g^{-1} = 0.0256\ kg/m^3$.

ANALYSIS: (a) The mass transfer coefficient, $h_m(x)$, will be largest at x = 0 and smallest at x = L for turbulent flow conditions. Hence, the trailing edge will dry last. <

(b) The evaporation rate on a per unit area basis, at the trailing edge where x = L, is given by the rate equation,

$$n''_A = h_{m,L}\left(\rho_{A,s} - \rho_{A,\infty}\right) = h_{m,L}\ \rho_{A,sat}\left(1 - \phi_\infty\right)$$

For turbulent flow the appropriate correlation for estimating $h_{m,L}$ is of the form

$$Sh_x = h_{m,x} x/D_{AB} = 0.0296\ Re_x^{4/5}\ Sc^{1/3}.$$

Substituting numerical values,

$$Re_L = \frac{u_\infty L}{\nu_B} = \frac{60 \times 10^3\ m/h}{3600\ s/h} \times 6m/15.89 \times 10^{-6}\ m^2/s = 6.29 \times 10^6$$

$$Sc = \frac{\nu_B}{D_{AB}} = 15.89 \times 10^{-6}\ m^2/s/0.26 \times 10^{-4}\ m^2/s = 0.611$$

$$h_{m,L} = \left(0.26 \times 10^{-4}\ m^2/s/6m\right) \times 0.0296\ \left(6.29 \times 10^6\right)^{4/5} \left(0.611\right)^{1/3} = 0.0299\ m/s.$$

Hence, the evaporation flux (rate per unit area) is

$$n''_A = 0.0299\ m/s \times 0.0256\ kg/m^3\ \left(1 - 0.85\right) = 1.15 \times 10^{-4}\ kg/s \cdot m^2. \quad <$$

COMMENTS: Recognize how the heat-mass analogy is utilized and the appropriate correlation selected from Table 7.7.