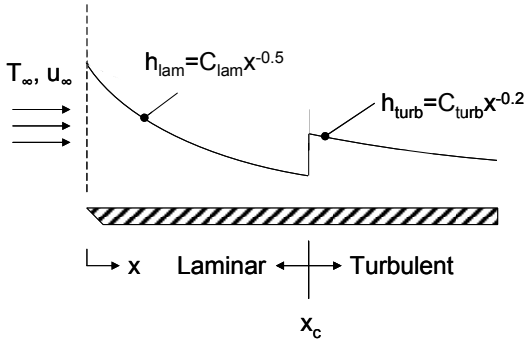
## PROBLEM 6.18

**KNOWN:** Air flow over a flat plate of known length, location of transition from laminar to turbulent flow, value of the critical Reynolds number.

**FIND:** (a) Free stream velocity with properties evaluated at T = 350 K, (b) Expression for the average convection coefficient, $\bar{h}_{lam}(x)$, as a function of the distance x from the leading edge in the laminar region, (c) Expression for the average convection coefficient $\bar{h}_{turb}(x)$, as a function of the distance x from the leading edge in the turbulent region, (d) Compute and plot the local and average convection coefficients over the entire plate length.

**SCHEMATIC:**




**ASSUMPTIONS:** (1) Steady-state conditions, (2) Constant properties.

**PROPERTIES:** Table A.4, air (T = 350 K): k = 0.030 W/m·K, $\nu = 20.92 \times 10^{-6}$ m$^2$/s, Pr = 0.700.

**ANALYSIS:**

(a) Using air properties evaluated at 350 K with $x_c$ = 0.5 m,

$$Re_{x,c} = \frac{u_\infty x_c}{\nu} = 5\times10^5$$

$$u_\infty = 5\times10^5\,\nu/x_c = 5\times10^5 \times 20.92\times10^{-6}\ m^2/s/0.5\,m = 20.9\,m/s \quad <$$

(b) From Eq. 6.9, the average coefficient in the laminar region, $0 \le x \le x_c$, is

$$\bar{h}_{lam}(x) = \frac{1}{x}\int_0^x h_{lam}(x)\,dx = \frac{1}{x}C_{lam}\int_o^x x^{-0.5}dx = \frac{1}{x}C_{lam}x^{0.5} = 2C_{lam}x^{-0.5} = 2h_{lam}(x) \quad (1) \quad <$$

(c) The average coefficient in the turbulent region, $x_c \le x \le L$, is

$$\bar{h}_{turb}(x) = \frac{1}{x}\left[\int_0^{x_c} h_{lam}(x)\,dx + \int_{x_c}^x h_{turb}(x)\,dx\right] = \left[C_{lam}\left.\frac{x^{0.5}}{0.5}\right|_0^{x_c} + C_{turb}\left.\frac{x^{0.8}}{0.8}\right|_{x_c}^{x}\right]$$

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$$\bar{h}_{turb}(x) = \frac{1}{x}\left[2C_{lam}x_c^{0.5} + 1.25C_{turb}\left(x^{0.8} - x_c^{0.8}\right)\right] \quad (2) <$$

(d) The local and average coefficients, Eqs. (1) and (2) are plotted below as a function of x for the range $0 \le x \le L$.