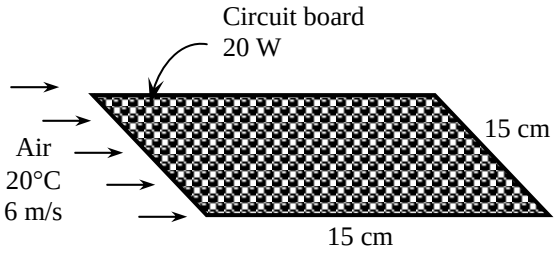
12-53 A circuit board is cooled by air. The surface temperatures of the electronic components at the leading edge and the end of the board are to be determined.

Assumptions **1** Steady operating conditions exist. **2** The critical Reynolds number is $\mathrm{Re}_{cr} = 5\times10^5$. **3** Radiation effects are negligible. **4** Any heat transfer from the back surface of the board is disregarded. **5** Air is an ideal gas with constant properties.

Properties Assuming the film temperature to be approximately 35°C, the properties of air are evaluated at this temperature to be (Table A-22)

$$k = 0.0265\ \mathrm{W/m.°C}$$
$$\nu = 1.655\times10^{-5}\ \mathrm{m^2/s}$$
$$\mathrm{Pr} = 0.7268$$



Analysis (*a*) The convection heat transfer coefficient at the leading edge approaches infinity, and thus the surface temperature there must approach the air temperature, which is 20°C.

(*b*) The Reynolds number is

$$\mathrm{Re}_x = \frac{Vx}{\nu} = \frac{(6\ \mathrm{m/s})(0.15\ \mathrm{m})}{1.655\times10^{-5}\ \mathrm{m^2/s}} = 5.438\times10^4$$

which is less than the critical Reynolds number but we assume the flow to be turbulent since the electronic components are expected to act as turbulators. Using the Nusselt number uniform heat flux, the local heat transfer coefficient at the end of the board is determined to be

$$Nu_x = \frac{h_x x}{k} = 0.0308\,\mathrm{Re}_x^{\,0.8}\,\mathrm{Pr}^{1/3} = 0.0308(5.438\times10^4)^{0.8}(0.7268)^{1/3} = 170.1$$
$$h_x = \frac{k_x}{x}Nu_x = \frac{0.02625\ \mathrm{W/m.°C}}{0.15\ \mathrm{m}}(170.1) = 29.77\ \mathrm{W/m^2.°C}$$

Then the surface temperature at the end of the board becomes

$$\dot{q} = h_x(T_s - T_\infty) \longrightarrow T_s = T_\infty + \frac{\dot{q}}{h_x} = 20°\mathrm{C} + \frac{(20\ \mathrm{W})/(0.15\ \mathrm{m})^2}{29.77\ \mathrm{W/m^2.°C}} = \mathbf{49.9°C}$$

Discussion The heat flux can also be determined approximately using the relation for isothermal surfaces,

$$Nu_x = \frac{h_x x}{k} = 0.0296\,\mathrm{Re}_x^{\,0.8}\,\mathrm{Pr}^{1/3} = 0.0296(5.438\times10^4)^{0.8}(0.7268)^{1/3} = 163.5$$
$$h_x = \frac{k_x}{x}Nu_x = \frac{0.02625\ \mathrm{W/m.°C}}{0.15\ \mathrm{m}}(163.5) = 28.61\ \mathrm{W/m^2.°C}$$

Then the surface temperature at the end of the board becomes

$$\dot{q} = h_x(T_s - T_\infty) \longrightarrow T_s = T_\infty + \frac{\dot{q}}{h_x} = 20°\mathrm{C} + \frac{(20\ \mathrm{W})/(0.15\ \mathrm{m})^2}{28.61\ \mathrm{W/m^2.°C}} = \mathbf{51.1°C}$$

Note that the two results are close to each other.

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