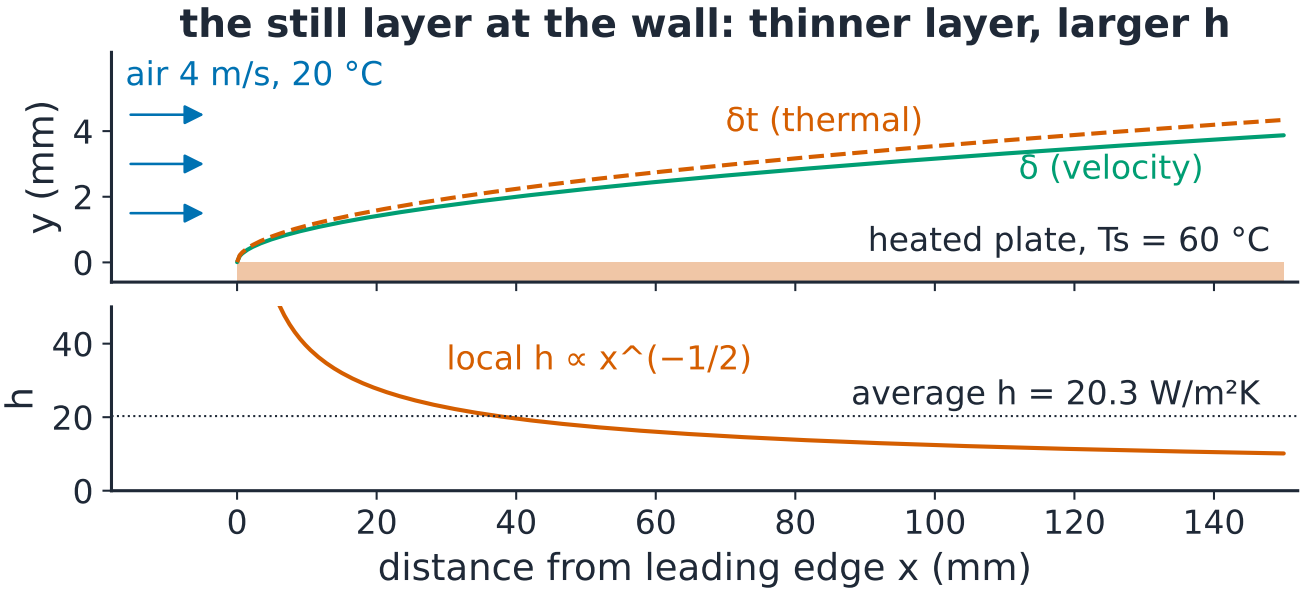
Exercise walk-through

# 10.3 Convection

University Mechanical Engineering

# The thermal boundary layer




Air 4 m/s on 150 mm: $Re = 37\,500$, $Nu = \mathbf{114.7}$, $h = \mathbf{20.3}$ W/m$^2$K.

# Water inside the pipe

1. **Flow** 16.8 L/s in 80 mm at 40 °C: $V = 3.34$ m/s, $Re = \mathbf{4.06 \times 10^5}$.
2. **Range** Dittus-Boelter needs $Re > 10^4$, $0.6 < Pr < 160$ - here $Pr = 4.32$.
3. **Nu** $Nu = 0.023 Re^{0.8} Pr^{0.4} = \mathbf{1268}$, $h \approx \mathbf{10\,000}$ W/m$^2$K.

## Decision

This is why the inside film resistance was negligible in the pipe network.

# Exercises 2.1·2.3

**2.1** Air flows at 5 m/s along a plate 0.2 m long. Find $Re_L$ and say whether the flow is laminar. [2]

**2.2** Find the average Nusselt number (one decimal) and $h$ (one decimal, W/(m$^2$ · K)). [3]

**2.3** The plate is 0.3 m wide and 40 K above the air. Find the heat loss from one face (one decimal, W). [2]

# Exercises 2.1·2.3

**2.1** Air flows at 5 m/s along a plate 0.2 m long. Find $Re_L$ and say whether the flow is laminar. [2]

**2.1**

- $Re_L = VL/\nu = 5 \times 0.2/(1.6 \times 10^{-5}) = \mathbf{62\,500}$.
- Below $5 \times 10^5$, so laminar over the whole plate.

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**2.2** Find the average Nusselt number (one decimal) and $h$ (one decimal, W/(m$^2\cdot$K)). [3]

**2.2**

- $Nu = 0.664 Re_L^{1/2} Pr^{1/3} = 0.664 \times 250 \times 0.892 = \mathbf{148.1}$.
- $h = Nu\,k/L = 148.1 \times 0.0265/0.2 = \mathbf{19.6}$ W/(m$^2\cdot$K).

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**2.3** The plate is 0.3 m wide and 40 K above the air. Find the heat loss from one face (one decimal, W). [2]

**2.3**

- $q = hA\,\Delta T = 19.6 \times (0.2 \times 0.3) \times 40 = \mathbf{47.1}$ W.

# Exercise 3.1

**3.1** Water at 40 °C flows at 1.5 m/s in a 25 mm tube and is heated by the wall. Find $Re$, justify Dittus–Boelter, and find $Nu$ (one decimal), $h$ (nearest W/(m$^2$ · K)) and the heat gained per metre of tube when the wall is 20 K above the water (two decimals, kW/m). Compare $h$ with the air value of 2.2. [7]

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**3.1**

- $Re = VD/\nu = 1.5 \times 0.025/(0.658 \times 10^{-6}) = \mathbf{56\,990}$.
- Turbulent ($Re > 10^4$), $Pr = 4.32$ inside 0.6 to 160, fluid heated: Dittus–Boelter with $Pr^{0.4}$ applies.
- $Nu = 0.023 Re^{0.8} Pr^{0.4} = \mathbf{263.4}$.
- $h = Nu\,k/D = 263.4 \times 0.631/0.025 = \mathbf{6647}$ W/(m$^2$ · K).
- $q' = h\pi D\,\Delta T = 6647 \times \pi \times 0.025 \times 20 = \mathbf{10.44}$ kW/m.
- About 340 times the air value: water's conductivity and the thin turbulent wall layer make liquid-side resistances small.