# 10.3 Convection

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

**KEY WORDS** Nusselt number • Prandtl number

## Objective

Find a convection coefficient from a correlation: work out the Reynolds number, choose the correlation that fits the flow, find the Nusselt number and turn it into $h$ and a heat flow.

## 1 Key knowledge and worked examples

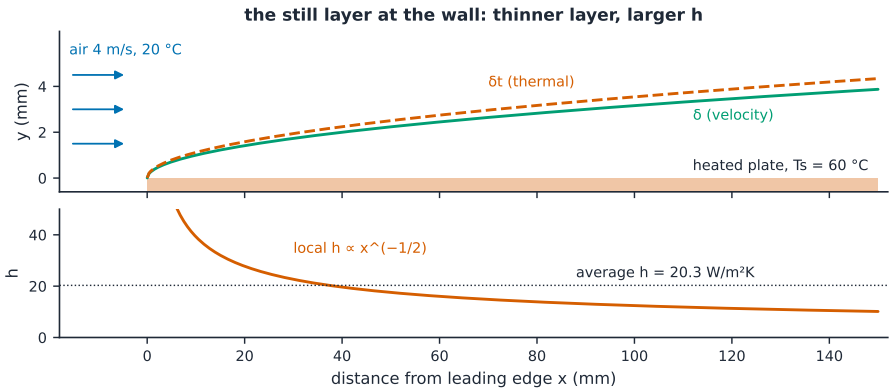
### From Reynolds to h

- **Nusselt number** $Nu = hL/k_f$: the dimensionless wall temperature gradient. **Prandtl number** $Pr = \nu/\alpha$.
- Flat plate, laminar ($Re_L < 5\times10^5$), average: $Nu = 0.664 Re_L^{1/2} Pr^{1/3}$.
- Tube, turbulent ($Re > 10^4$), fluid heated (Dittus–Boelter): $Nu = 0.023 Re^{0.8} Pr^{0.4}$.
- Then $h = Nu\,k_f/L$ and $q = hA\,\Delta T$.

### Worked example. Air over a plate

Air 4 m/s, 20 °C ($\nu = 1.6\times10^{-5}$ m$^2$/s, $k = 0.0265$, $Pr = 0.71$), plate 150 mm long.

- $Re_L = VL/\nu = 4\times0.15/(1.6\times10^{-5}) = \mathbf{37\,500}$: laminar.
- $Nu = 0.664 Re_L^{1/2} Pr^{1/3} = \mathbf{114.7}$.
- $h = Nu\,k/L = 114.7\times0.0265/0.15 = \mathbf{20.3}$ W/(m$^2\cdot$K).




## 2 Practice

Air: $\nu = 1.6\times10^{-5}$ m$^2$/s, $k = 0.0265$ W/(m$\cdot$K), $Pr = 0.71$. Water at 40 °C: $\nu = 0.658\times10^{-6}$ m$^2$/s, $k = 0.631$ W/(m$\cdot$K), $Pr = 4.32$.

**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$^2\cdot$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]

## 3 Exam-style questions

**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]