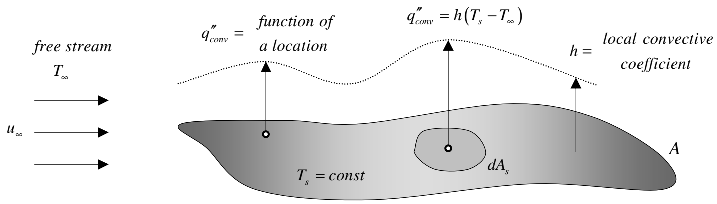
INTRODUCTION TO CONVECTION

Objective : determine convective coefficient h

6.2 CONVECTION COEFFICIENT

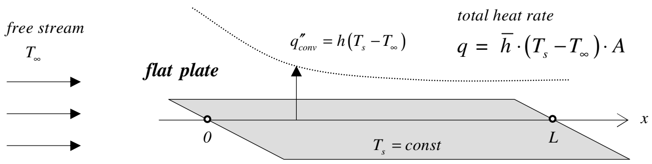


$$q = \int_A q''_{conv} dA = \int_A h(T_s - T_\infty) dA = (T_s - T_\infty)\int_A h\, dA$$

$$= \underbrace{\frac{\int_A h\, dA}{A}}_{\bar{h}} \cdot A \cdot (T_s - T_\infty) = \bar{h} \cdot A \cdot (T_s - T_\infty)$$

averaged convective coefficient

$$\bar{h} = \frac{\int_A h\, dA}{A}$$



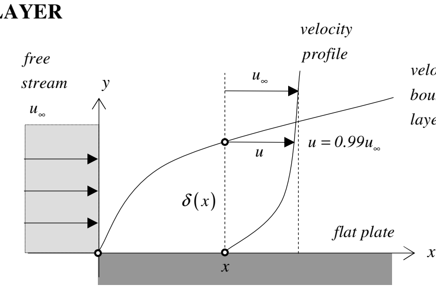
total heat rate

$$q = \bar{h} \cdot (T_s - T_\infty) \cdot A$$

averaged convective coefficient for flat plate

$$\bar{h}_L = \frac{\int_0^L h\, dx}{L}$$

6.1 VELOCITY BOUNDARY LAYER



friction coefficient $C_f = \dfrac{\tau_s}{\rho u_\infty^2 / 2}$

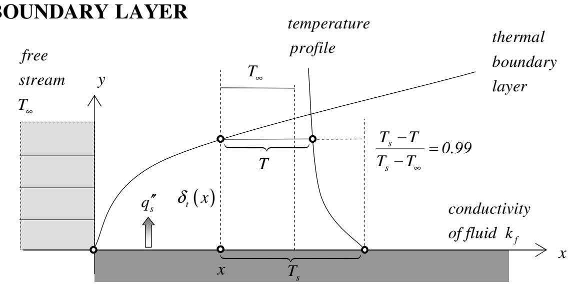
surface shear stress $\tau_s = \mu \left.\dfrac{\partial u}{\partial y}\right|_{y=0}$

dynamic viscosity $\mu \left[\dfrac{kg}{s \cdot m} = \dfrac{N \cdot s}{m^2}\right]$

kinematic viscosity $\nu \left[\dfrac{m^2}{s}\right]$

$$\mu = \rho \nu$$

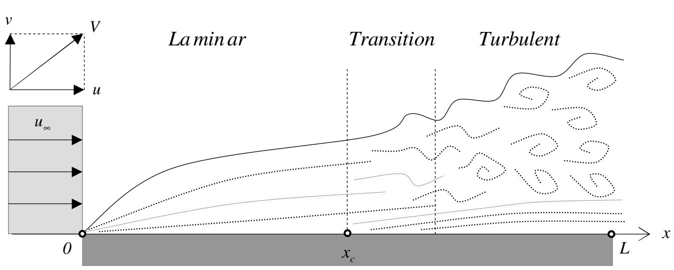
THERMAL BOUNDARY LAYER



local convective coefficient:

$$\overbrace{-k_f \left.\frac{\partial T}{\partial y}\right|_{y=0}}^{q''_s \text{ local heat flux}} = h(T_s - T_\infty) \quad \Rightarrow \quad h = \frac{-k_f \left.\dfrac{\partial T}{\partial y}\right|_{y=0}}{T_s - T_\infty}$$

6.3–6.4 BOUNDARY LAYER EQUATIONS



$$Re_{cr} = \frac{u_\infty \cdot x_c}{\nu} = 5 \cdot 10^5 \quad (\textit{flat plate})$$

$$Re_x = \frac{\rho u_\infty x}{\mu} = \frac{u_\infty x}{\nu}$$ **Reynolds Number**

The Convection Equations (*Appendix D 1–5*)

Boundar Layer Approximations (6.25):

$$\frac{\partial^2 u}{\partial x^2} << \frac{\partial^2 u}{\partial y^2} \qquad \frac{\partial^2 T}{\partial x^2} << \frac{\partial^2 T}{\partial y^2}$$

Boundary Layer Equations (Laminar) (6.26–6.30)

Boundary Layer Equations (dinesionless) (6.35–6.36)

dimensionless variables (6.31–33):

$$x^* = \frac{x}{L} \qquad y^* = \frac{y}{L}$$

$$u^* = \frac{u}{V} \qquad v^* = \frac{v}{V}$$

$$T^* = \frac{T - T_s}{T_\infty - T_s}$$

6.5 PARAMETERS

Reynolds $Re_L = \dfrac{VL}{\nu}$

$$u^* = f\left(x^*, y^*, Re_L, \frac{\partial p^*}{\partial x^*}\right)$$

Prandtl $Pr = \dfrac{\nu}{\alpha}$

$$T^* = f\left(x^*, y^*, Re_L, Pr, \frac{\partial p^*}{\partial x^*}\right)$$

Nusselt $Nu = \dfrac{hL}{k}$

$$Nu = f\left(x^*, Re_L, Pr\right)$$

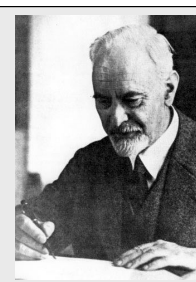
$\overline{Nu} = \dfrac{\bar{h}L}{k}$

$$\overline{Nu} = f\left(Re_L, Pr\right)$$

Boundary Layer Analogy:

the systems with the same parameters have the same heat convection coefficients

Convective coefficient h will be determined from Nu: $h = \dfrac{Nu \cdot k}{L}$



Ludwig Prandtl (1875–1953)