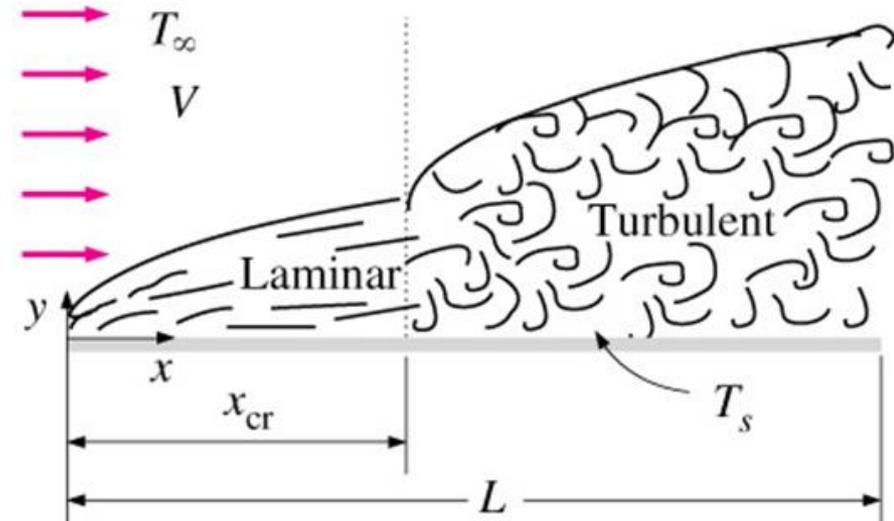
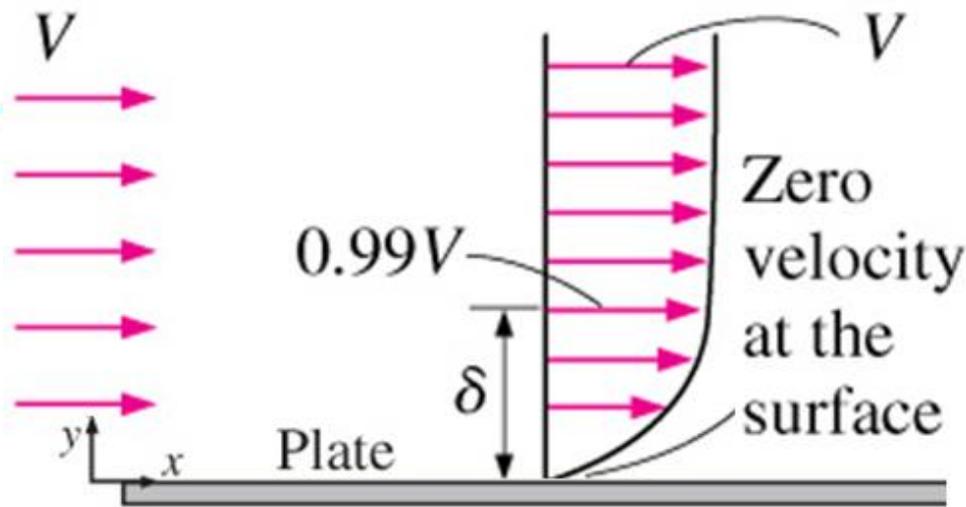


# **TRANSFERÊNCIA DE CALOR: CONVECÇÃO FORÇADA EXT.**



- **ESCOAMENTO EXTERNO: CAMADA LIMITE**
- **PLACA ISOTÉRMICA - REGIME: LAMINAR vs. TURBULENTO**
- **ESCOAMENTOS AO REDOR DE CILINDROS / HASTES**

# Escoamento externo: camada limite



**Nº de Reynolds:**  $Re_x = \frac{\rho u_\infty x}{\mu} \xrightarrow{v = \frac{\mu}{\rho}} Re_x = \frac{u_\infty x}{\nu}$

**Nº de Prandtl:**  $Pr = \frac{\nu}{\alpha}$

transição  $\downarrow x = x_{cr}$

$Re_c \cong 5 \times 10^5$

# Escoamento sobre placa isotérmica

- Escoamento laminar paralelo à placa isotérmica

- Exemplo: correlações de Pohlhausen  $\begin{cases} Re_L < 5 \times 10^5 \\ T = T_{\text{filme}} \end{cases}$

$$Nu_L = 0.664 Re_L^{1/2} Pr^{1/3}, \quad 0.6 < Pr < 10$$

$$Nu_L = 0.678 Re_L^{1/2} Pr^{1/3}, \quad Pr \rightarrow \infty$$

- Escoamento turbulento paralelo à placa isotérmica

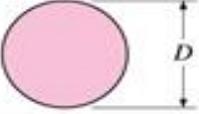
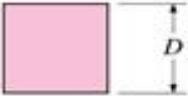
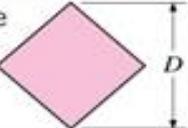
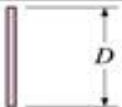
- Exemplo: correlação de Whitaker  $\begin{cases} 2 \times 10^5 < Re_L < 5.5 \times 10^6 \\ 0.7 < Pr < 380 \end{cases}$

$$Nu_L = 0.036 (Re_L^{4/5} - Re_c^{4/5}) Pr^{0.43} + 0.664 Re_c^{1/2} Pr^{1/3}$$



# Ao redor de cilindros, hastes, barras



Cross-section	Fluid	Range of Re	Nusselt number
Circle 	Gas or liquid	0.4–4	$Nu = 0.989Re^{0.330} Pr^{1/3}$
		4–40	$Nu = 0.911Re^{0.385} Pr^{1/3}$
		40–4000	$Nu = 0.683Re^{0.466} Pr^{1/3}$
		4000–40,000	$Nu = 0.193Re^{0.618} Pr^{1/3}$
		40,000–400,000	$Nu = 0.027Re^{0.805} Pr^{1/3}$
Square 	Gas	5000–100,000	$Nu = 0.102Re^{0.675} Pr^{1/3}$
Square (tilted 45°) 	Gas	5000–100,000	$Nu = 0.246Re^{0.588} Pr^{1/3}$
Hexagon 	Gas	5000–100,000	$Nu = 0.153Re^{0.638} Pr^{1/3}$
Hexagon (tilted 45°) 	Gas	5000–19,500 19,500–100,000	$Nu = 0.160Re^{0.638} Pr^{1/3}$ $Nu = 0.0385Re^{0.782} Pr^{1/3}$
Vertical plate 	Gas	4000–15,000	$Nu = 0.228Re^{0.731} Pr^{1/3}$
Ellipse 	Gas	2500–15,000	$Nu = 0.248Re^{0.612} Pr^{1/3}$