Chapter 4 of Heinsohn & Cimbala: Useful Tables

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Table 4.3 Convection heat transfer and mass transfer relationships (abstracted from Bird et al., 1960 and Incropera and DeWitt, 1990).

1. *Air flowing over a flat surface* $\quad Nu = \dfrac{Lh}{k} \qquad Pr = \dfrac{c_p \mu}{k} \qquad Re = \dfrac{\rho U_\infty L}{\mu}$

   Laminar flow: $\quad Pr > 0.6 \qquad Re < 5 \times 10^5 \qquad Nu = 0.664 (Re)^{0.5} (Pr)^{0.33}$

   Turbulent flow: $\quad 0.6 < Pr < 60 \qquad 5 \times 10^5 < Re < 10^8 \qquad Nu = \left(0.037 (Re)^{0.80} - 871\right)(Pr)^{0.33}$

2. *Air flowing through a cylindrical duct* $\quad Sh = k_G \dfrac{R_u T L P_{am}}{D_{ja} P}$

   Turbulent flow: $\quad 0.6 < Sc < 300 \qquad 4{,}000 < Re < 60{,}000 \qquad Sh = 0.023 (Re)^{0.83} (Sc)^{0.33}$

3. *Air flowing over a stationary sphere* (L = D)

   Laminar or turbulent flow: $\quad 0.71 < Pr < 380 \qquad 3.5 < Re < 7.6 \times 10^4 \qquad 1.0 < \mu_\infty/\mu_S < 3.2$

$$Nu = 2 + \left[0.4\sqrt{Re} + 0.06 (Re)^{2/3}\right](Pr)^{0.4} \left(\frac{\mu_\infty}{\mu_s}\right)^{1/4}$$

   where viscosity μ_∞ is evaluated at the far-field temperature and viscosity μ_s is evaluated at the average surface temperature.

4. *External flowing over plates and cylinders* (Pr > 0.7) $\quad Nu = C\ (Re)^{a_2} (Pr)^{0.33}$

	Re	**C**	**a_2**
Horizontal cylinder (D = L):	0.4-4	0.989	0.330
	4-40	0.911	0.385
	40-4000	0.683	0.466
	4000-40,000	0.193	0.618
	40,000-400,000	0.027	0.805
Square (L by L), flow 90° to flat surface:	5000-100,000	0.246	0.588
Square (L by L), flow 45° to a flat surface:	5000-100,000	0.102	0.675
Semi-infinite vertical plate (height L) flow 90° to flat surface:	4000-15,000	0.288	0.731

5. *Air flowing through a fixed bed of pellets* $\quad Sc = 0.6 \qquad \varepsilon = 1 - \dfrac{D_p a_s}{6}$

   Low Re flow: $\quad 90 < Re < 4{,}000 \qquad Nu = \dfrac{2.06}{\varepsilon} (Re)^{0.422} Pr (Sc)^{-0.67}$

   High Re flow: $\quad 5{,}000 < Re < 10{,}300 \qquad Nu = \dfrac{20.4}{\varepsilon} (Re)^{0.185} (Sc)^{-0.67} Pr$

   where a_s = total pellet surface area per volume of fixed bed