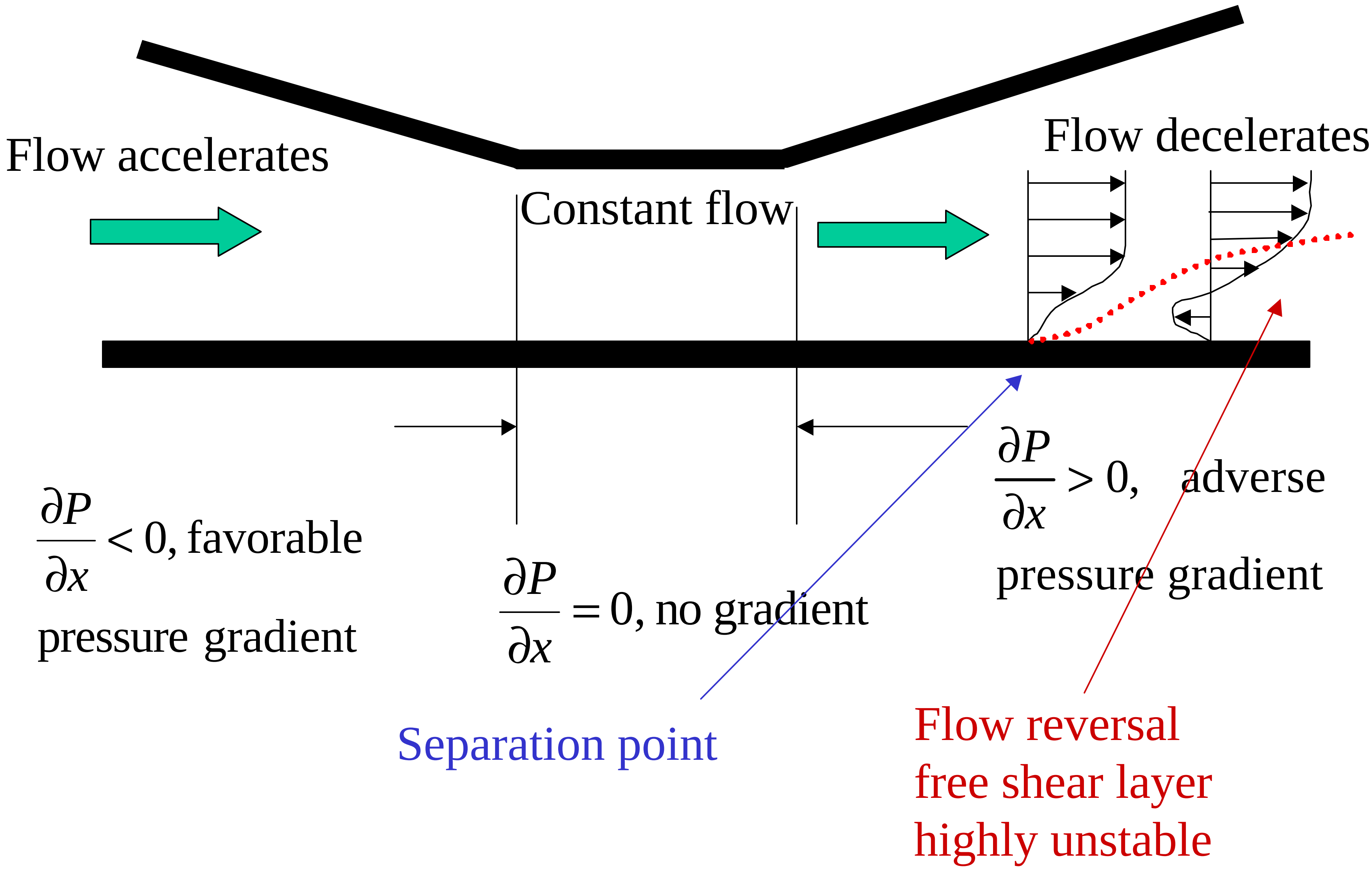
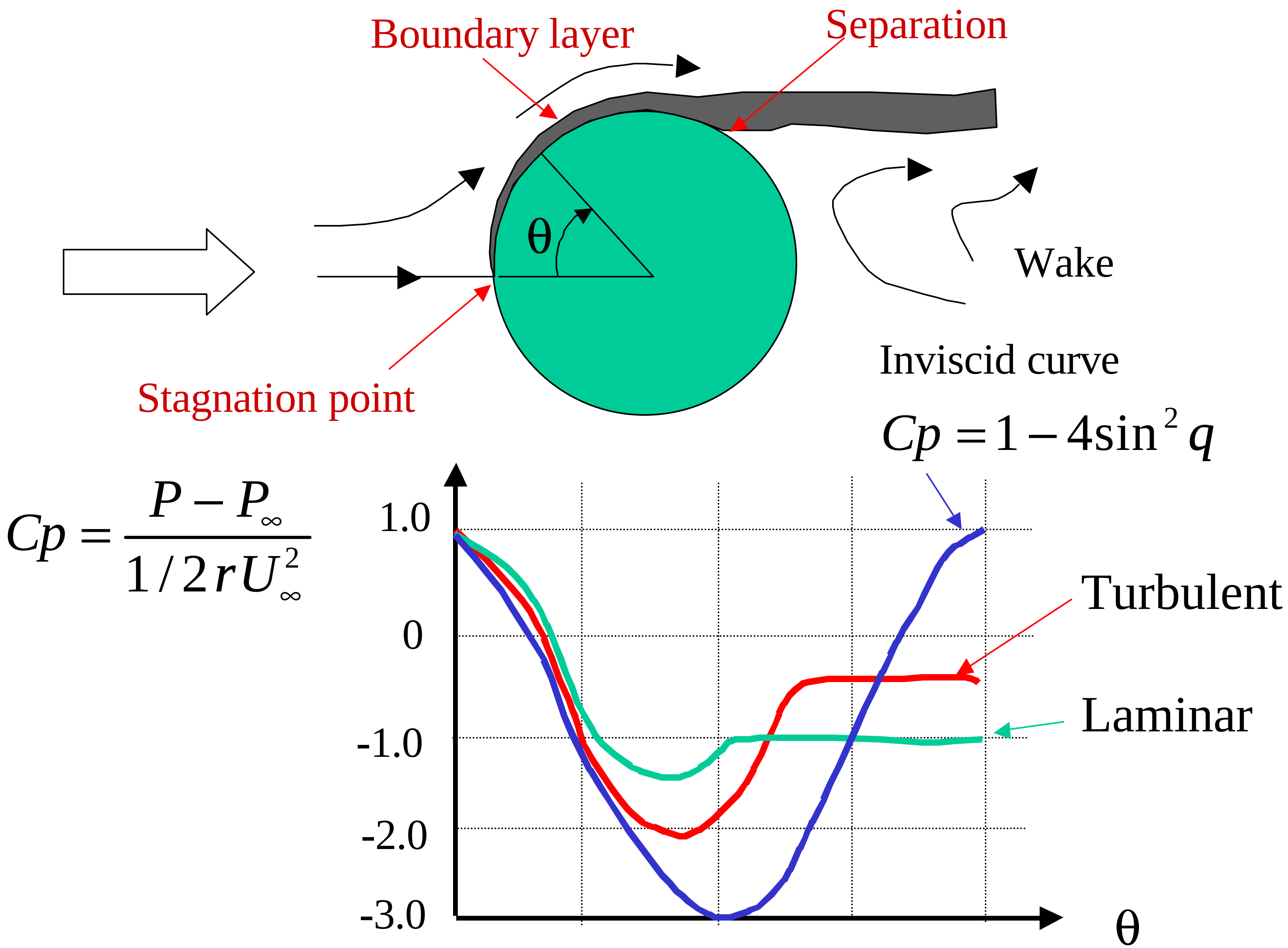
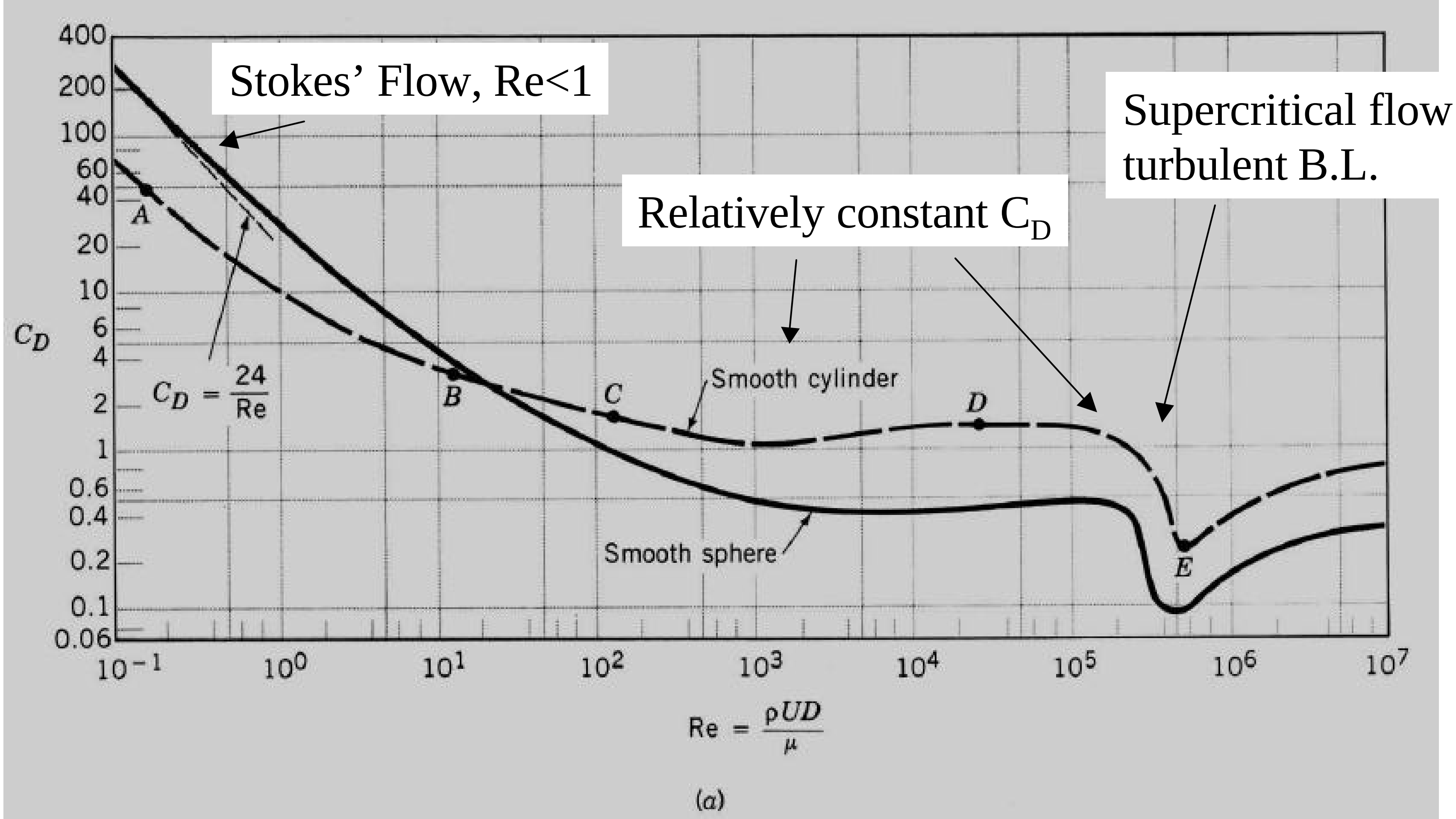
Boundary Layer and separation



Flow Separation

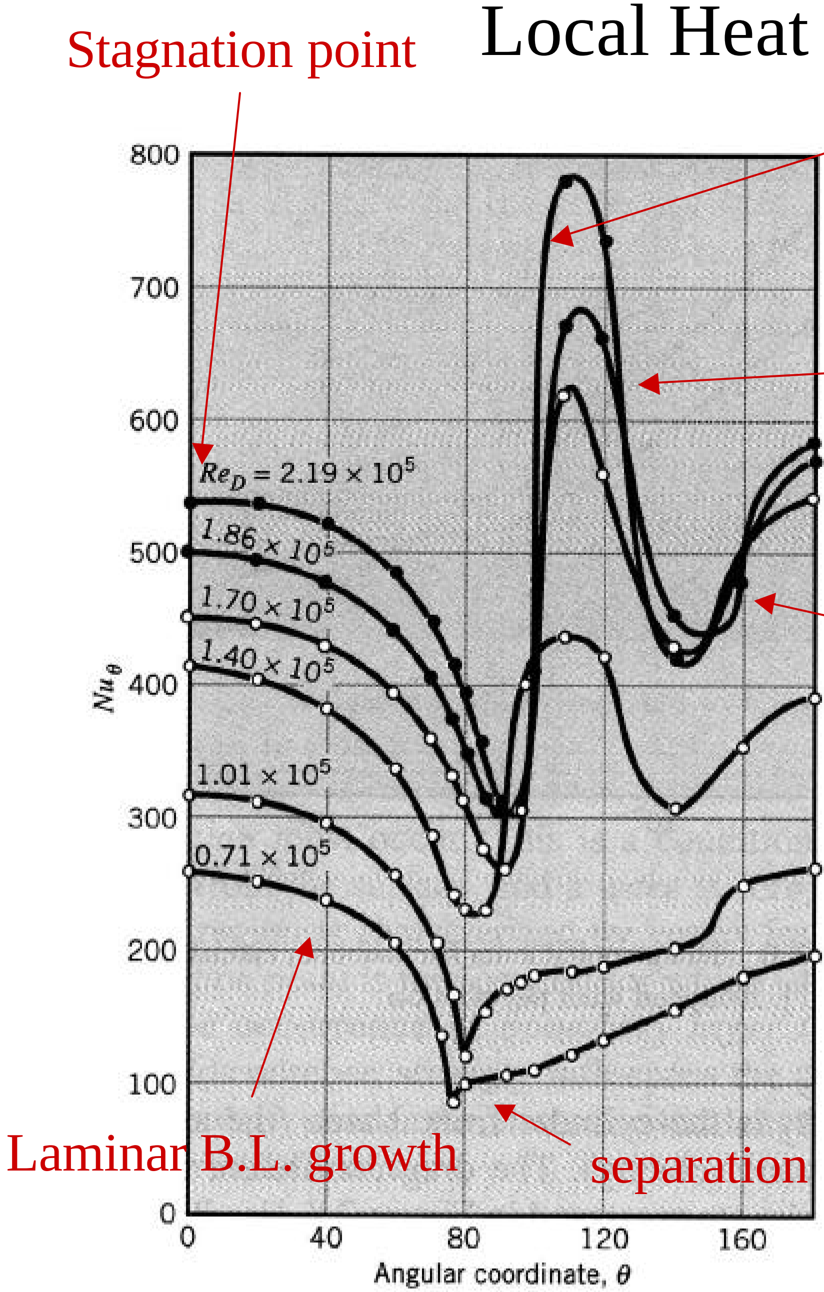


Drag Coefficient: C_D

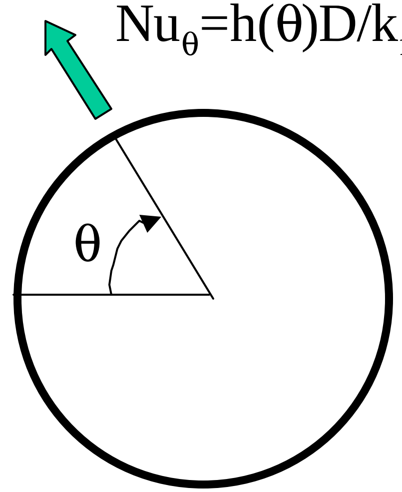


■ **FIGURE 9.23** (*a*) **Drag coefficient as a function of Reynolds number for a smooth circular cylinder and a smooth sphere.**

Local Heat Transfer Distribution



$q_\theta'' = h(\theta)(T_s - T_\infty)$,
$Nu_\theta = h(\theta)D/k_f$



Local Nusselt number for airflow normal to a circular cylinder.
(figure 10-22 from the ITHT text)

Averaged Nusselt Number Correlations of Cylinders in Cross Flows

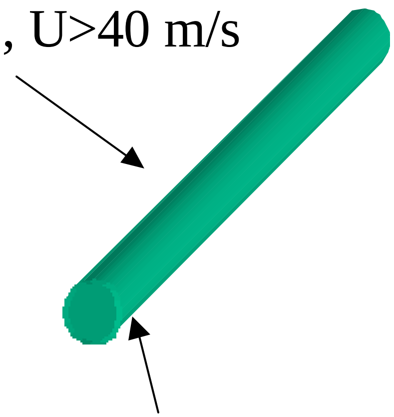
Note 1: averaged Nusselt number correlations for the circular cylinder flows can be found in chapter 10-5. Correlations for other noncircular cylinders in cross flow can also be found in this chapter (see Table 10-3).

Note 2: Heat transfer between a tube bank (tube bundle) and cross flow is given in many HT textbooks (for example: see chapter 7 of "Introduction to Heat Transfer" by Incropera & DeWitt. The configuration is important for many practical applications, for example, the multiple pass heat exchanger in a condenser unit. The use of tube bank can not only save the operating space but also can enhance heat transfer. The wake flows behind each row of tubes are highly turbulent and can greatly enhance the convective heat transfer. In general, one can find an averaged convection coefficient using empirical correlation.

Note 3: Because of its compactness, pressure drop across a tube bank can be also significant and warrants careful design consideration.

Example

A hot-wire anemometer is a flow device used to measure flow velocity based on the principle of convective heat transfer. Electric current is passing through a thin cylindrical wire to heat it up to a high temperature, that is why it is called "hot-wire". Heat is dissipated to the fluid flowing the wire by convection heat transfer such that the wire can be maintained at a constant temperature. Determine the velocity of the airstream (it is known to be higher than 40 m/s and has a temperature of 25°C), if a wire of 0.02 mm diameter achieved a constant temperature of 150°C while dissipating 50 W per meter of electric energy.



Air (87.5°C), Pr=0.707, $\nu=15\times10^{-6}$ m^2/s, k=0.026 W/m.K

Example (cont.)

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

$$50 = \bar{h}(p\, DL)(150 - 25)$$

$$\bar{h} = \frac{50}{p\,(0.02\times10^{-3})(1)(125)} = 6369(W/m^2.K)$$

$$Nu = \frac{\bar{h}D}{k} = \frac{6369(0.00002)}{0.026} = 4.90$$

$$\mathrm{Re} > \frac{\mathrm{VD}}{n} = \frac{(40)(0.00002)}{15\times10^{-6}} = 53,$$

assume 4000 > Re > 40, use equation (10-37)

$$Nu = (0.683)\,\mathrm{Re}^{0.466}\ \mathrm{Pr}^{1/3}$$

$$4.90 = (0.683)\left(VD/n\right)^{0.466}\ (0.707)^{1/3}$$

$V = 65.9(m/s)$, Re $= 87.9$ satisfy the range of validity