9.77

9.77 Air flows past two equal sized spheres (one rough, one smooth) that are attached to the arm of a balance as is indicated in Fig. P9.77. With $U = 0$ the beam is balanced. What is the minimum air velocity for which the balance arm will rotate clockwise?

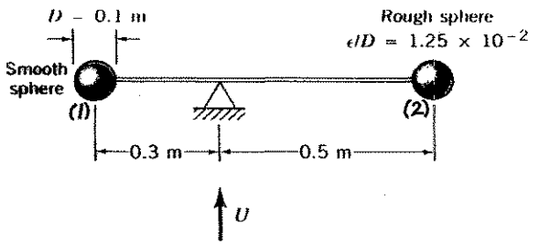


FIGURE P9.77

For clockwise rotation to start, $\Sigma M_0 < 0$

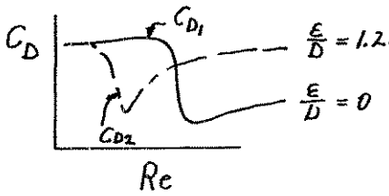
That is $0.3\,\mathcal{D}_1 \geq 0.5\,\mathcal{D}_2$, where $\mathcal{D}_1 = C_{D_1}\frac{1}{2}\rho U_1^2 A_1$ and

$$\mathcal{D}_2 = C_{D_2}\frac{1}{2}\rho U_2^2 A_2$$

Thus, $0.3\,C_{D_1}\frac{1}{2}\rho U_1^2 A_1 = 0.5\,C_{D_2}\frac{1}{2}\rho U_2^2 A_2$, or since $U_1 = U_2$ and $A_1 = A_2$ this gives

$$C_{D_2} = 0.6\,C_{D_1} \qquad (1)$$

Consider the curves in Fig. 9.25 with $\frac{\varepsilon}{D} = 0$ and $\frac{\varepsilon}{D} = 1.25\times10^{-2}$



Trial and error solution to find Re so that Eq. (1) is satisfied.

Assume $Re = 6\times10^4 \longrightarrow C_{D_1} = 0.5$, $C_{D_2} = 0.46$ or $\frac{C_{D_2}}{C_{D_1}} = 0.92 \neq 0.6$

Assume $Re = 8\times10^4 \longrightarrow C_{D_1} = 0.5$, $C_{D_2} = 0.21$ or $\frac{C_{D_2}}{C_{D_1}} = 0.42 \neq 0.6$

Assume $Re = 7\times10^4 \longrightarrow C_{D_1} = 0.5$, $C_{D_2} = 0.33$ or $\frac{C_{D_2}}{C_{D_1}} = 0.66 \approx 0.6$

Thus, $Re \approx 7.1\times10^4 = \frac{UD}{\nu} = \frac{(0.1\text{m})\,U}{1.46\times10^{-5}\frac{\text{m}^2}{\text{s}}}$ or $U \approx \underline{\underline{10.4\ \frac{\text{m}}{\text{s}}}}$