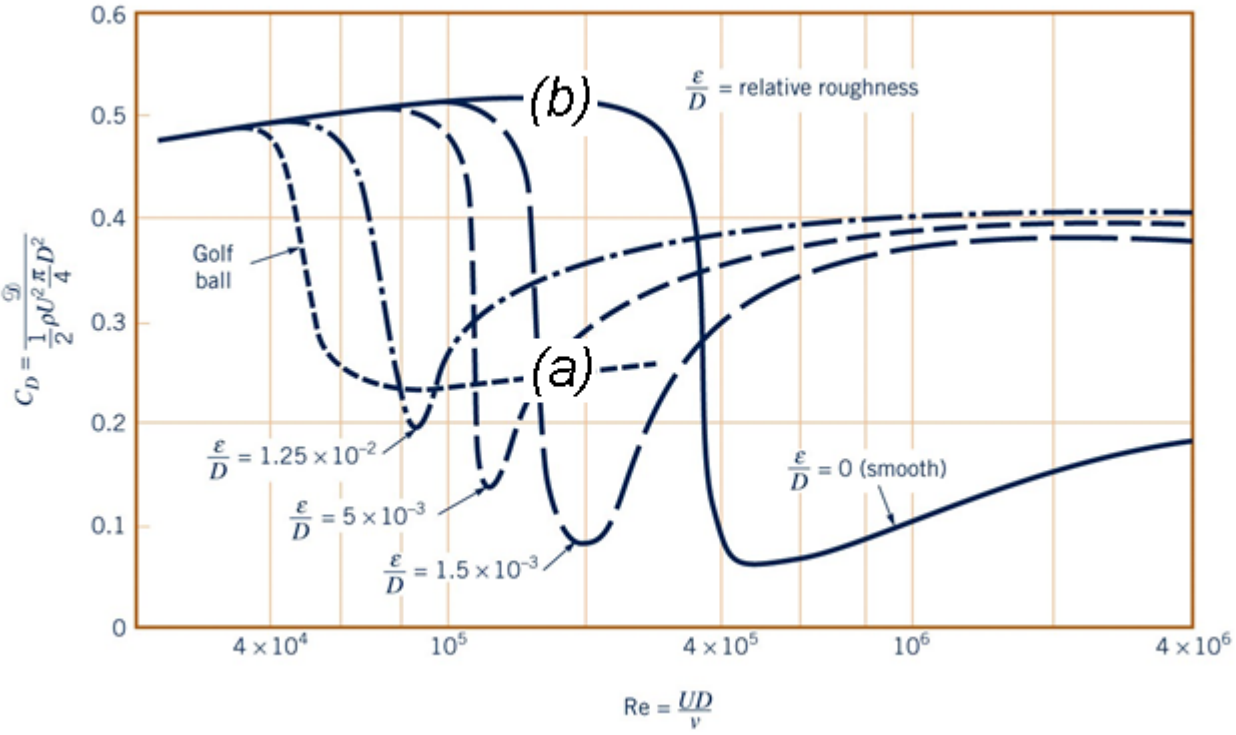
Example: Effect of Surface Roughness

A well-hit golf ball (diameter D = 1.69 in.) can travel at U = 200 ft/s as it leaves the tee. Determine the drag on (a) a standard golf ball and (b) a smooth golf ball for the conditions given.



Solution:

For either ball, the drag can be obtained from

$$\mathcal{D} = \frac{1}{2}\rho U^2 \frac{\pi}{4} D^2 C_D \qquad (1)$$

where the drag coefficient C_D is given in the figure as a function of the Reynolds number and surface roughness. For the golf ball in standard air

$$Re = \frac{UD}{\nu} = \frac{(200\,\text{ft/s})(1.69/12\,\text{ft})}{1.57 \times 10^{-4}\,\text{ft}^2/\text{s}} = 1.79 \times 10^5$$

The corresponding drag coefficients are C_D = 0.25 for the standard golf ball and C_D = 0.51 for the smooth golf ball. Hence, from Eq. 1 for the standard golf ball

$$\mathcal{D} = \frac{1}{2}(0.00238\,\text{slugs/ft}^3)(200\,\text{ft/s})^2 \frac{\pi}{4}\left(\frac{1.69}{12}\,\text{ft}\right)^2 (0.25) = 0.185\,\text{lb}$$

and for the smooth golf ball

$$\mathcal{D} = \frac{1}{2}(0.00238\,\text{slugs/ft}^3)(200\,\text{ft/s})^2 \frac{\pi}{4}\left(\frac{1.69}{12}\,\text{ft}\right)^2 (0.51) = 0.378\,\text{lb}$$

Note that dimples on golf balls can create a turbulent boundary layer and reduce the aerodynamic drag, allowing longer drives than with smooth balls.