CHAPTER 9

Boundary Layers

9.1. Boundary Layer Structure

Boundary layers are the regions near a boundary in which rotational and viscous effects are significant. The various flow field regions are shown in Figure 9.1.

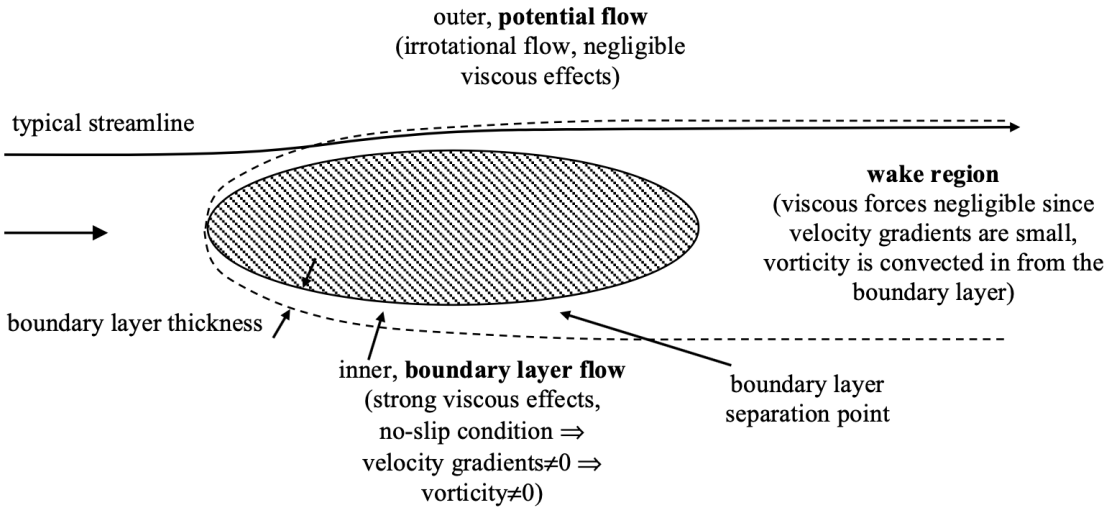

Figure 9.1. A schematic illustrating different regions in the external flow around an object.

9.2. Boundary Layer Thickness Definitions

Before continuing further, we should define what we mean by the "thickness" of a boundary layer. There are three commonly used definitions.

(1) *99% boundary layer thickness, δ or $\delta_{99\%}$.* This thickness definition is the most commonly used definition. The boundary layer thickness, δ, is defined as the distance from the boundary at which the fluid velocity, u, is 99% that of the outer velocity, U (Figure 9.2),

$$\boxed{u(y=\delta)=0.99U}. \tag{9.1}$$

(2) *displacement thickness, δ_D or δ^*.* The displacement thickness, δ_D, is the distance at which the undisturbed outer flow is displaced from the boundary by a stagnant layer of fluid that removes the same mass flow as the actual boundary layer profile (Figure 9.3),

$$\int_0^\infty \rho(U-u)dy = \rho U\delta_D, \tag{9.2}$$

$$\boxed{\delta_D = \int_0^\infty \left(1-\frac{u}{U}\right)dy \approx \int_0^\delta \left(1-\frac{u}{U}\right)dy.} \tag{9.3}$$