**BOUNDARY LAYER THICKNESS**

The **boundary layer thickness** $\delta$ is the distance from the plate at which the fluid velocity is within 99% the magnitude of the outer flow velocity.

**BOUNDARY LAYER DISPLACEMENT THICKNESS**

Consider the flow over a flat plate for an inviscid and a viscous fluid.

The velocity deficit in the BL caused by the retardation of the flow due to viscous effects creates a flow rate deficit (gray area in viscous case above).

This flow rate deficit could be compensated for by moving the location of the plate in the inviscid by an appropriate distance $\delta^*$ called the **boundary layer displacement thickness**.

The BL displacement thickness can be calculated as:

$$\delta^* b U = \int_0^\infty (U - u) b dy$$

where $b$ is the width of the plate normal to the page.

Therefore:

$$\delta^* = \int_0^\infty \left(1 - \frac{u}{U}\right) dy$$
Using the Blasius solution: \[ \delta^* = \frac{1.721x}{\sqrt{Re}}, \]

Physically: the BL displacement thickness is the amount of displacement of a streamline due to the retardation of the flow in the BL due to viscous effects.

**BOUNDARY LAYER MOMENTUM THICKNESS**

Similarly, the velocity deficit in the BL causes a momentum flux deficit. This momentum flux deficit can be expressed as:

\[
\int_0^\infty \rho(U-u)udA = \int_0^\infty \rho(U-u)u\,dy = \rho b \int_0^\infty u(U-u)\,dy
\]

This momentum flux deficit can be compensated for by moving the plate in the inviscid case by a distance \( \theta \) called the **boundary layer momentum thickness**:

This quantity can be calculated as:

\[ \rho b U^2 \theta = \rho b \int_0^\infty u(U-u)\,dy, \]

where \( b \) is the width of the plate normal to the page.

Therefore:

\[ \theta = \int_0^\infty \frac{u}{U} \left(1 - \frac{u}{U}\right)\,dy \]

Using the Blasius solution: \[ \theta = \frac{0.664x}{\sqrt{Re}}. \]