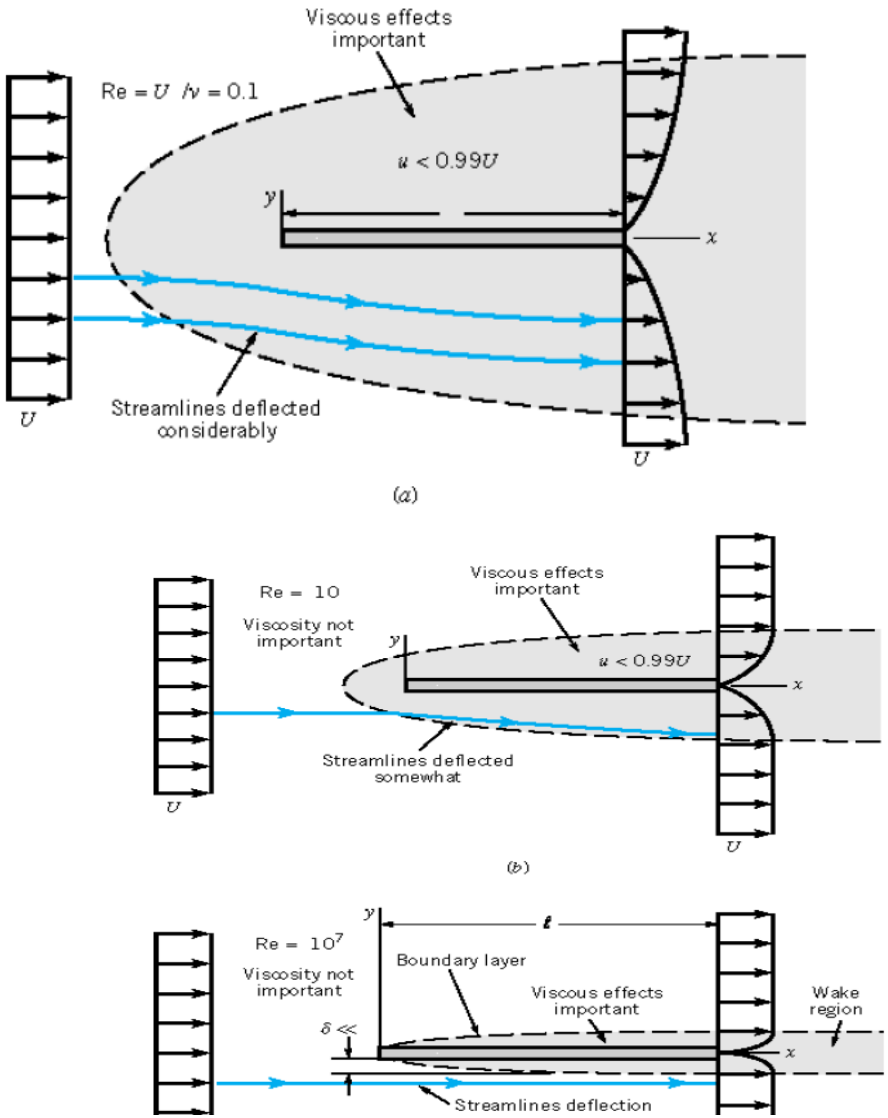
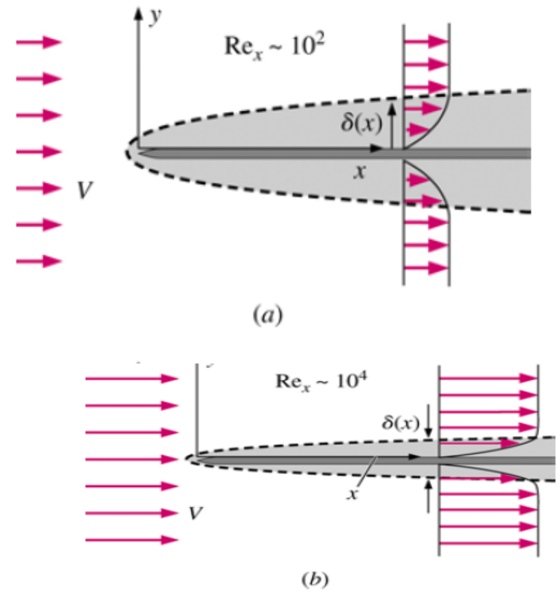
FLUID MECHANICS FOR MECHANICAL ENGINEERING (ME 208F)

Section D:
Boundary Layer Flow - I

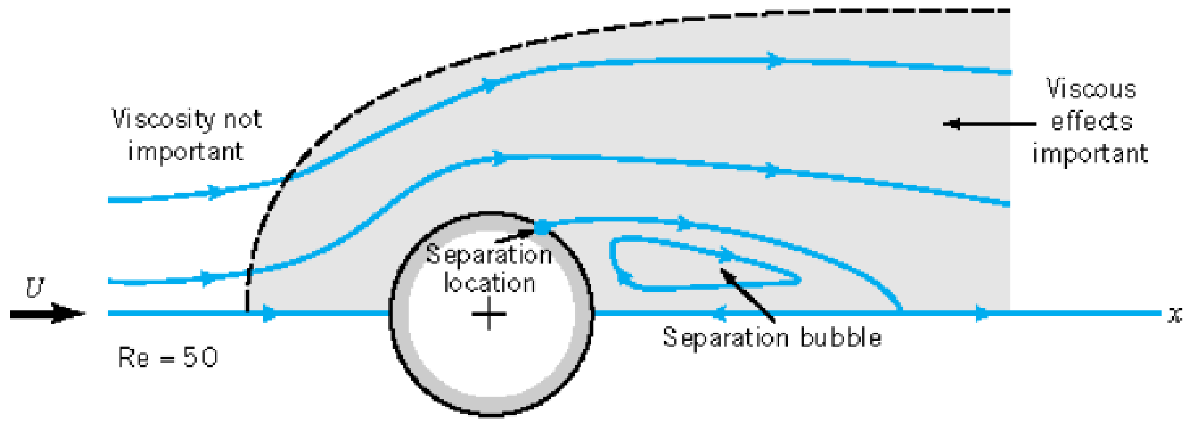
Boundary Layer

In 1904, Prandtl developed the concept of the boundary layer, which provides an important link between ideal-fluid flow (inviscid irrotational flow) and real-fluid flow (viscous rotational flow). It was accepted that for fluids with relatively small viscosity or more exactly, flow with a high Reynolds number), the effect of internal friction in the fluid is appreciable only in a narrow region surrounding the fluid boundaries. Therefore the flow sufficiently far away from the solid boundaries may be considered as ideal low (in which effects of viscosity are neglected). However, flow near the boundaries suffers retardation by the boundary shear forces and at the boundaries the velocity is zero (noslip condition). A steep velocity gradient is therefore resulted in a thin layer adjacent to the boundaries, which is known as the **boundary layer.** It is of great significance when behavior of real fluid is considered. For example, it explains the d'Alembert's paradox – the drag force experienced by a cylinder in stream that cannot be predicted with a potential theory.

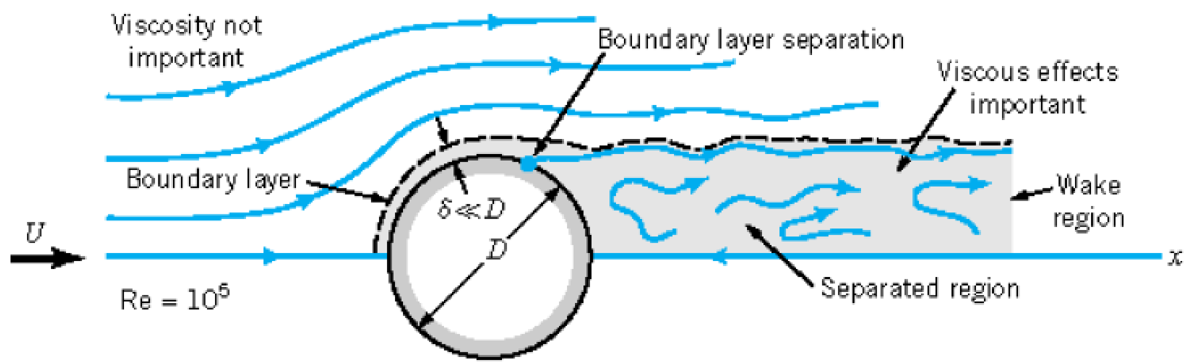




Flow of a uniform stream parallel to a flat plate. The larger the Reynolds number, the thinner the boundary layer along the plate at a given x-location.


Viscosity not important
Viscous effects important
Separation location
Separation bubble
U
x
Re = 50

(b)


Viscosity not important
Boundary layer separation
Viscous effects important
Boundary layer
δ ≪ D
D
Wake region
Separated region
U
x
Re = 10⁵

(c)