Department of Mechanical Engineering

ME/AA507 Fluid Mechanics
Homework #4, due 03-14-2019

Problem 1

Use the Von Karman-Pohlhausen integral method to calculate approximate boundary layer thicknesses (displacement (δ) and momentum (θ)) and friction coefficients (C_f) along a flat plate, zero-pressure-gradient boundary layer, using the following approximations for the velocity profile inside the boundary layer:

- Linear profile: $V_x = V_{outer}(y/\delta)$
- Cubic profile: $V_x = V_{outer}[(y/\delta)^3 - 3(y/\delta)^2 + 3(y/\delta)]$
- Sinusoidal profile: $V_x = V_{outer}\ sin(\pi/2 \cdot y/\delta)$
- Exponential profile: $V_x = V_{outer}\ (1 - e^{\alpha \cdot y/\delta})$. Determine the numerical value of the constant α if δ represents the 99% velocity boundary layer thickness.

Compare quantitatively against the Blasius solution. Which of the velocity profiles represents a better approximation? Point out the two boundary conditions that all profiles satisfy from construction?

Problem 2

The problem of using suction and blowing to reduce the drag on a flat plate has been considered for quite some time. Let's study a particular example of this problem.

Fluid flows over a flat plate with a steady uniform velocity. The plate is porous and a uniform suction is applied on the plate so that the suction velocity at the surface is constant $V_y(x, y = 0) = -V_0$. Because of this suction velocity, there is a characteristic length scale (Hint: no similarity solution) and the problem becomes fully developed at a certain distance from the leading edge.

Using the boundary layer equations, solve for the velocity profile inside the boundary layer.

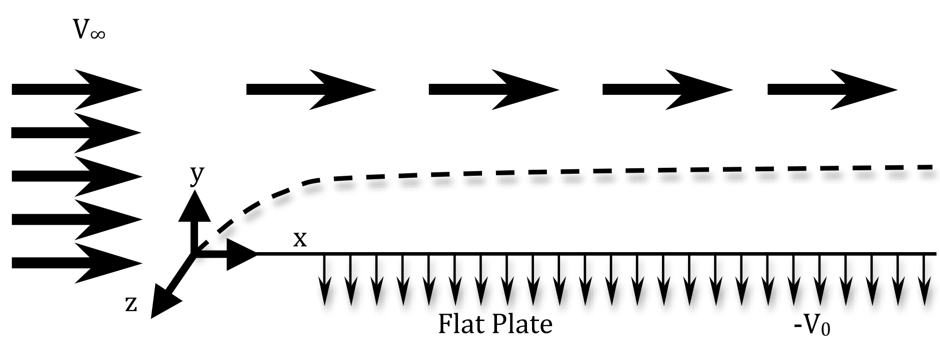

Figure 1: Sketch of the uniform flow over a flat plate with constant suction velocity.