ABE 307
Fall 2017
Homework 7
Assigned: 11/10/2017
Due: 11/17/2017
(Potential Points < 80)

1. Assume a simple velocity profile as given below for boundary layer in case of laminar viscous flow over a flat plate. The fluid approaches the plate with uniform velocity V_∞ . The boundary layer develops on both sides of the plate. (40)

$$\frac{V_x}{V_\infty} = \frac{y}{\delta}$$

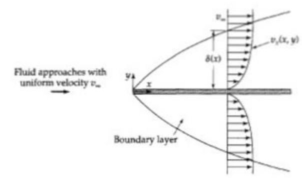

Fig. 4.4-2. Boundary-layer development near a flat plate of negligible thickness.

   a. Show that the velocity profile is acceptable for the boundary layer.
   b. Deduce the form of boundary layer thickness in this scenario.
   c. Compute the % error over the boundary layer thickness derived for the same flow scenario using the velocity form in Example 4.4-1 of your textbook.
   d. Deduce the form of drag force on the plate in this velocity profile.
   e. Compute the % error in estimation of drag force using this velocity profile over the velocity profile given in Example 4.4-1 of your textbook.

2. Air at 1 atm and 20 deg C flows tangentially on both sides of a thin, smooth flat plate of width W = 10 ft, and of length L = 3 ft in the direction of the flow. The velocity outside the boundary layer is constant at 20 ft/sec. (15)
   a. Compute the local Reynolds number $Re_x = \frac{x\,V_\infty}{\mu/\rho}$ at the trailing edge.
   b. Assuming laminar flow, compute the approximate boundary-layer thickness, in inches at the trailing edge. Use the velocity profile as in Example 4.4-1
   c. Assuming laminar flow, compute the total drag force on the plate in lb_f.

3. In what sense are the potential flow solutions and the boundary layer flow solutions complementary? (5)

4. The pressure drop, Δp, over a certain length of horizontal pipe is assumed to be a function of velocity, V, of the fluid in the pipe, the pipe diameter, D, and the fluid density and viscosity (ρ and μ). (20)
   a. Show that this flow can be described in dimensonless form as a “pressure coefficient”, $C_p = \frac{\Delta p}{\rho\, v^2}$ that depends on the Reynolds number, Re = ρvD/μ.
   b. The data given in table was obtained in an experiment involving a fluid with ρ = 2 slugs/ft3, μ = 2 x (10^{-3}) lb.s/ft^2., and D = 0.1ft. Plot a dimensionless graph that can be used for scale up using the experimental data. Use a power law equation between the pressure coefficient and the Reynolds number. You can use Excel or your calculator to get this relationship. [Note 1 Slug = 14.59 Kg. It is an imperial unit and data is from an old experiment which reported things in English Units]

c. What are the limitation on the applicability of your equation obtained in part (b) for design of other systems?

V, ft/sec	Δp = lb/ft^2
3	192
11	704
17	1088
20	1280