MAE 101B, Spring 2009

Homework 3

Due Thursday, April 30, in class

Guidelines: Please turn in a *neat* homework that gives all the formulae that you have used as well as details that are required for the grader to understand your solution. Required plots should be generated using computer software such as Matlab or Excel.
Please refrain from copying. Refer to the course outline for what constitutes copying

1. A wind tunnel consists of a fan, a smooth pipe and a smooth diffuser as shown in the figure. The fan supplies a power of $5.2\,kW$ to create an air flow with velocity $30\,m/s$ in the pipe. The pipe has diameter of $0.8\,m$ and length of $1.1\,m$. The tunnel is open to atmosphere at both ends. Two diffusers with different length L_1 and L_2 are tested. The flow exits the tunnel at 15 m/s when the diffuser with length L_1 is used and it is 10 m/s when that with length L_2 is used. Use $\rho = 1.22\,kg/m^3$ and $\mu = 1.8 \cdot 10^{-5}\,kg/m - s$ for air.

a) Find the expression that relates L_1 and L_2.

b) Calculate the loss coefficient K_{diff} when the diffuser with length L_2 is used.

2.

a) Show that the curvature of the velocity profile d^2u/dy^2 must be zero at the wall in a boundary layer with zero pressure gradient.

b) The parabolic profile assumption in a laminar boundary layer can be replaced by the following polynomial profile (which satisfies the zero curvature requirement) in the Karman momentum integral analysis:

$$\frac{u}{U} = 2\frac{y}{\delta} - 2\frac{y^3}{\delta^3} + \frac{y^4}{\delta^4}$$

Obtain the shape factor, H. Obtain an expression that relates δ/x to Re_x.

3. A missile is launched from the ground with a net upward acceleration of $2\,m/s^2$. Assume that the boundary layer on the fin surface can be approximated as that on a flat plate.

a) What is the expected length of the laminar boundary layer L_{lam} on the fin when the missile hits 5 km elevation?

b) What is L_{lam} at 10 km elevation?

Note: See table A2 and A6 in the Appendix for atmospheric air properties at different elevation.

4. A thin trapezoidal flat plate is immersed in SAE 10 oil ($\rho = 890\,kg/m^3$ and $\mu = 0.29\,kg/m-s$) as shown in the figure. The oil flows with velocity $5\,m/s$.

a) What is the drag force if the flow is from the left of the plate?

b) What is the drag force if the flow is from the right of the plate?

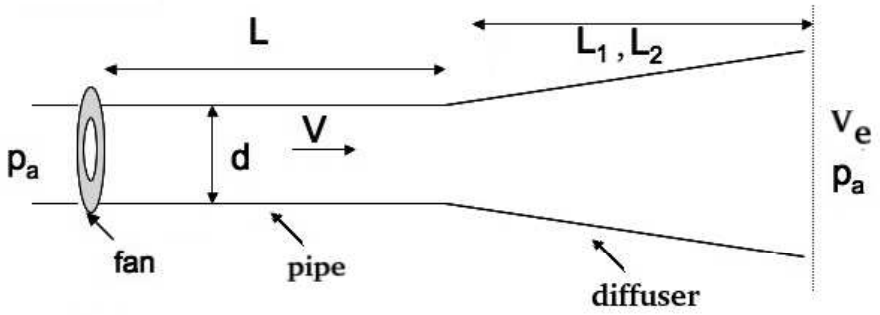
5. Water flows at velocity U over a thin flat plate. A boundary layer with thickness δ forms on the plate.

a) Assume two-dimensional steady incompressible flow with zero pressure gradient. Give the governing equations for the boundary layer as well as the boundary conditions.

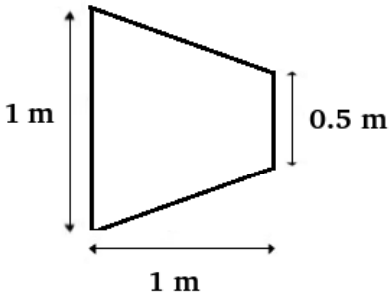
b) Rewrite the result obtained in part (a) in term of stream function ψ. State the boundary conditions for ψ.

c) Show that for $\psi = U\delta(x)f(\eta)$ the PDEs in part (b) can be reduced to a single ODE with constant coefficients. Here, $f' = u/U$ is an explicit function of $\eta = y/\delta(x)$. Give the boundary conditions for the ODE.

Ungraded problems From text. 7.8, 7.27.



Problem 1



Problem 4