Assignment -2 (Similarity Solns. to Laminar External B.L heat transfer) Due: Feb 21, 2013

Note: The assignments will be individually evaluated and penalized if found to be copied from colleagues.

1) Apply scaling analysis to the boundary layer momentum equation to obtain the relationship between boundary layer thickness, $\delta$, and local Reynolds number, $Re_x$. Note that this is a simpler alternative over the rigorous proof through which the same result was arrived at in the class. Also extend the scaling argument to energy equation and for small values of Prandtl number show that $\frac{\delta_t}{\delta} = Pr^{-0.5}$

2) Plot the solution to the Blasius similarity equation for a flat plate by plotting the power series expansion for $f'$ vs $\eta$ retaining up to four dominant terms. Use the value of 0.332 for the curvature at the wall $\alpha = f(0)''$ into the series expansion. Identify the value of $\eta$ corresponding to $f' \sim 0.99$.

3) Use the shooting technique to solve the Falkner-Skan similarity equation for values of the exponent $m$ equal to 0 and 1 corresponding to flat plate and stagnation flow. Tabulate the value of $f(0)''$ for these configurations. Also, plot the profiles of $f'$ vs $\eta$. For the case of $m=0$, compare the velocity profile obtained from the numerical solution with that of the series expansion plotted in problem 2.

Note: The details on the number of points used, and the grid size must be mentioned. Also the criteria used to monitor solution convergence must be included. Pls. attach a copy of the program written any language of your choice along with the assignment.

4) Solve the similarity energy equation for non-dimensional temperature $\theta$ following the solution to the velocity in problem 3. For the case of $m=0$, plot the temperature profiles as a function of Prandtl number $Pr$. Tabulate the values of $\theta(0)'$ for $Pr = 0.1, 0.7, 1$ and 100 for both $m = 0$ and 1. Compare the flat plate values with that of slope obtained from Pohlhausen’s relationship between $\theta(0)'$ and $Pr$. Comment on the results obtained.

5) Solve the Falkner-Skan similarity momentum and energy equation using shooting technique for the case of flat plate boundary layer for values of blowing ratios of -0.75 and 0.5 respectively. Tabulate the values of $f(0)''$ and $\theta(0)'$ for $Pr = 0.7$. Construct a relationship between local Nusselt no. $Nu_x$ and $Re_x$ for these two cases.

6) If a constant heat flux is applied to the flat plate instead of a uniform temperature, the similarity energy equation gets modified accordingly. Assuming that a non dimensional temperature $\theta$ can be defined for the case of uniform wall heat flux as $\theta = \frac{T-T_{\infty}}{\Delta T_{scale}}$. Show based on scaling argument that $\Delta T_{scale} = \frac{q^*}{k \sqrt{\frac{\rho c}{U}}}$. Substitute for $T$ from the above expression in terms of $\theta$ and $\Delta T_{scale}$ into the B.L energy equation and show that the similarity solution for the energy equation can be expressed as follows:

$$\theta'' + \frac{Pr}{2} (f \theta' - f' \theta) = 0$$

subject to BCS: $\theta'(0) = -1$ and $\theta'(\infty) = 0$. Explain (don’t solve) its solution using shooting method.