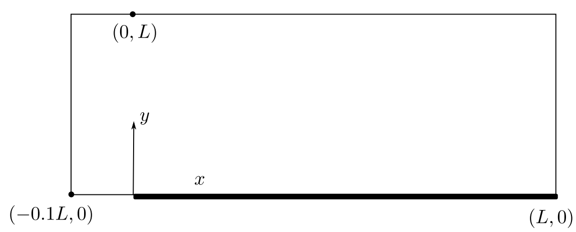
Flat-Plate Boundary Layer

Homework 8

Handed out: November 19
Due in: December 5

Solve for the flow over a flat plate at Reynolds number 10 million using the `simpleFoam` solver. Use the best discretization settings that you have found from the previous homework problems. Set the under-relaxation factors to 0.3 and 0.7 for `p` and `U` respectively. Run for a sufficient number of iterations so that the solution has converged. I suggest plotting the initial residual of the solution to each linear system (semi-log), and monitoring the solution itself. You can use the utility `foamLog` to post-process the `log` file and to extract the residuals. For example, the initial residual for the x-component of velocity is written to `Ux_0`. Use the Spalart-Allmaras turbulence model. See the website `http://turbmodels.larc.nasa.gov/spalart.html` for a nice summary of different versions of this model and results.

Generate four meshes, each with a different near-wall spacing. I suggest using the topology shown in the figure below. Keep the number of points in x the same between the four grids, and you could do the same in y, or you can add points in y for the smaller y^+ grids. Try to generate meshes with near wall spacing of y^+ to be 0.5, 5, 50, and 500 on average.



Use the Spalart-Allmaras turbulence model set-up for an adaptive wall function. Use a free-stream value of the eddy-viscosity ratio of $\tilde{\nu}/\nu = 1$. The `airfoil2D` tutorial for the `simpleFoam` solver and the sample case `yplus05` will be helpful for the set-up for your homework. You may use the `yPlusRAS` utility to examine the value of y^+ after you compute a solution on each of the four grids.

(1) (5pts) Velocity Profile: Examine the streamwise velocity profile at the location $x/L = 0.75$. Generate two figures. In the first, plot the velocity on each grid and compare to the theoretical results: $u^+ = y^+$, and $u^+ = \frac{1}{0.41}\ln y^+ + 5.1$. Use semi-log scaling of the plot axes, and plot in the wall variables, u^+, y^+. To do this you will need to find the shear-stress on the wall. Use the `myWallShearStress` utility to calculate the stress on the plate. See `https://www.cfd-online.com/Wiki/Law_of_the_wall` for a review of the law of the wall.

For the second figure, plot the velocity in outer variables, u, y. Discuss the difference in the predicted results as a function of the near-wall spacing.

(2) (5pts) Wall Shear Stress Profile: Compare your numerical computation with the estimate from White:

$$c_f = \frac{2\tau_w}{\rho U^2} = \frac{0.455}{\ln^2(0.06Re_x)}$$

Hand in a figure for $c_f(x)$ from White, and from each of your grids. Discuss the results. In your opinion, which near-wall spacing(s) are sufficient to capture the wall-shear stress profile?