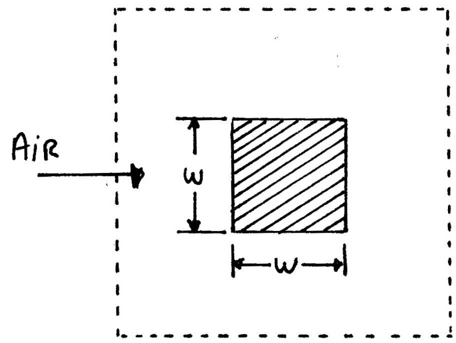
Computational Aerodynamics
Assignment 8 — Design Problem

Problem #1

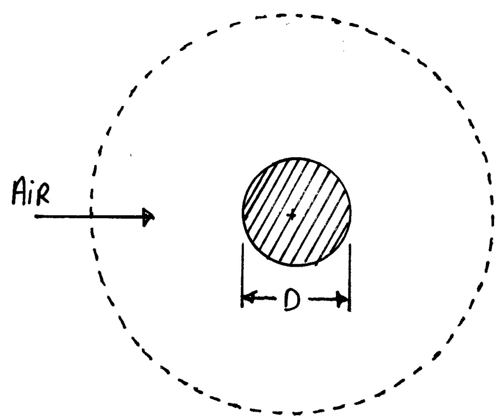
Consider air interacting with a long rod of square cross-section as follows:



The air in the freestream has a Mach number of 2.5, a pressure of 5 kPa, and a temperature of 300 K. The width of the cross section is of $W = 0.1$ m. The goal is to determine the drag coefficient C_D as accurately as possible while using as few computational resources as possible. Design a mesh that is optimal for this problem (i.e., that will yield the smallest product of error and computational time). Set the viscosity and thermal conductivity to zero.

Problem #2

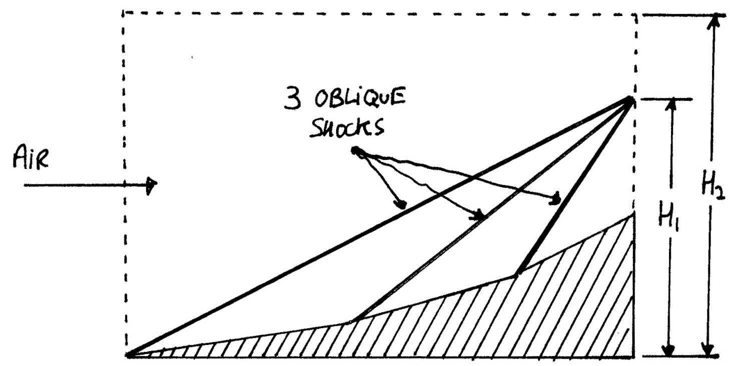
Consider air interacting with a long cylinder as follows:



The air in the freestream has a Mach number of 2.5, a pressure of 5 kPa, and a temperature of 300 K. The diameter of the cylinder is of $D = 0.1$ m. The goal is to determine the drag coefficient C_D as accurately as possible while using as few computational resources as possible. Design a mesh that is optimal for this problem (i.e., that will yield the smallest product of error and computational time). Set the viscosity and thermal conductivity to zero.

Problem #3

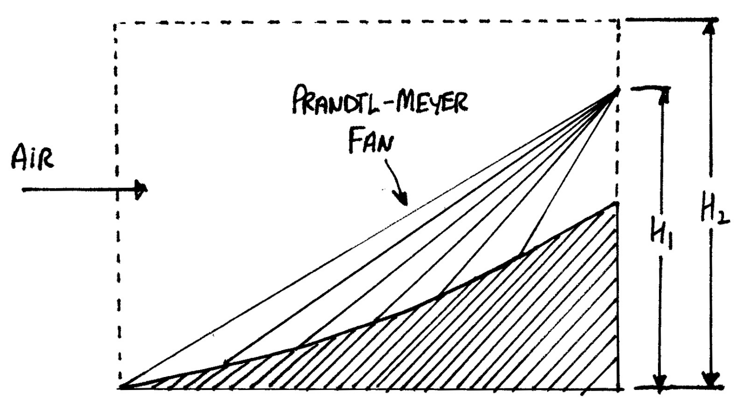
Consider air entering a scramjet inlet as follows:



The incoming air has a Mach number of 8, a pressure of 0.05 atm, and a temperature of 250 K. The inlet is designed such that the pressure at the inlet exit (after the three shocks) is 60 times higher than the pressure in the freestream. For optimal performance, the inlet is designed following the Oswatitch condition (i.e., the pressure ratio across each oblique shock is the same), and such that the three oblique shocks converge at one point. Take $H_1 = 1$ m, and $H_2 = 1.3H_1$. The goal is to determine the mass flux averaged stagnation pressure at the end of the inlet as accurately as possible while using as few computational resources as possible. Design a mesh that is optimal for this problem (i.e., that will yield the smallest product of error and computational time). Set the viscosity and thermal conductivity to zero.

Problem #4

Consider air entering a scramjet inlet as follows:



The incoming air has a Mach number of 8, a pressure of 0.05 atm, and a temperature of 250 K. The inlet is designed such that the pressure at the inlet exit (after the Prandtl-Meyer fan) is 60 times higher than the pressure in the freestream. For optimal performance, the inlet is designed so that the compression process is isentropic (i.e., all the Mach waves must converge at one point). Take $H_1 = 1$ m, and $H_2 = 1.3H_1$. The goal is to determine the mass flux averaged stagnation pressure at the end of the inlet as accurately as possible while using as few computational resources as possible. Design a mesh that is optimal for this problem (i.e., that will yield the smallest product of error and computational time). Set the viscosity and thermal conductivity to zero.

Instructions

The goal for each design problem is to optimize the mesh. An optimal mesh yields the lowest value of Ψ with Ψ being the product between error and computing time. Specifically, do the following:

(a) Choose a design problem. Some of the design problems are easier than others. In order of difficulty (from easiest to hardest): #1, #4, #2, and #3. I will give more points if you choose a more difficult problem.

(b) Create a mesh function of the mesh factor "mf". Thus, mf $=1$ will give the coarsest mesh, mf $=2$ will give the same mesh as mf $=1$ but with every cell divided in 4 cells, mf $=4$ will give the same mesh as mf $=2$ but with every cell divided in 4 cells, etc.

(c) Set up your initial conditions, boundary conditions, and physical model correctly.

(d) Set up the flux discretization scheme to FDS with either TVD and WENO interpolation.

(e) Estimate the maximum time step size that will yield positive coefficients as a function of mf. Set dt in the PredictorCorrector() module a bit smaller than this value.

(f) Modify the Post() module so that it outputs either $C_{\rm D}$ or mass flux averaged stagnation pressure at the domain exit when warp is called with the -opm flag.

(g) Determine through trial and error the amount of time that is needed to achieve a steady-state. Set tmax in the PredictorCorrector() module accordingly.

(h) Vary mf and determine its impact on either the drag coefficient or the mass flux averaged stagnation pressure. Estimate the error as a function of mf.

(i) Based on the results obtained, optimize the mesh and cluster more cells in areas where the property gradients are highest.

(j) Print out your mesh (with mf=1), your control file, a contour plot of the pressure at steady state, a vector plot of the velocity at steady state, and a table listing either drag coefficient or mass flux averaged stagnation pressure as a function of mf.

Due on Tuesday June 11th at 16:30.