Computational Heat & Fluid Flow (ME605)

Instructors: Dr. Rudra Narayan Roy & Dr. Sudhakar Yogaraj

School of Mechanical Sciences, IIT Goa

Assignment 4

Notes:

All the problems are required to be solved using finite volume method

You have to submit a report, and it should comprise of following details for each problem

i) The grid details (with a neat sketch)
ii) Discretization details
iii) Boundary condition implementation details
iv) A well-documented working code
v) Required output (plots/any other means)
vi) Analysis of the results

Penalty: Copying and submitting the code written by someone else will incur a huge penalty

---

1. Consider a one-dimensional convection-diffusion problem in a domain of L = 1. Two separate cases are to be considered: (i) $\rho = 1,\ \Gamma = 1,\ u = 1$ and (ii) $\rho = 1,\ \Gamma = 0.01,\ u = 3$. The boundary conditions for the transported variable ϕ are: (i) $x = 0,\ \phi = 0$ (ii) $\phi = L,\ \phi = 1$. Solve for the distribution of ϕ within the domain for each case. Implement CDS, upwind, hybrid and exponential scheme for each case. Plot the numerical results in the domain of interest for this purpose. With appropriate means i.e., with the obtained results comment on the accuracy, and on the suitability of each scheme with respect to the cell Peclet number.
2. Consider a steady hydrodynamically fully-developed flow entering a two-dimensional channel formed by two horizontal plates. The vertical distance between the plates is H = 2. The plates are subjected to a constant temperature of 100, and the flow entering the channel is at a uniform temperature of 50. Thus, this is a hydrodynamically fully-developed but thermally developing problem. Let the length of the channel be L = 40. The velocity profile everywhere is given by $u = 1.5\left(1 - 4y^2\right),\ v = 0$ where y is measured from the centerline of the channel.

The steady flow energy equation neglecting viscous dissipation is given by

$$\nabla \cdot \left(\rho c \vec{V} T \right) = \nabla \cdot \left(k \nabla T \right),$$

where the two-dimensional form is to be used. Use $\rho = 1,\ c = 100,\ k = 1$. Using the CDS, Upwind and Hybrid schemes, solve for the temperature field in the channel domain. Use a uniform grid and $\Delta x = \Delta y$. Use the condition $\partial T / \partial x = 0$ at the outflow boundary. Plot and compare the temperature profiles at various axial locations to demonstrate the development of the temperature field while using three different schemes. Additionally, do the following:

a) From the numerical solution, determine the bulk mean temperature at each axial location. You will need to employ an integration method to do this.

b) Using the bulk mean temperature data, determine the heat transfer coefficient at each axial location.

c) Determine the Nusselt number and plot the variation with respect to the axial distance.