APL 720: Lab 9

Submission deadline: 22 April, 2024

Consider the flow in a two-dimensional rectangular domain as shown in the figure below. The fluid (water) enters through the left face at a uniform velocity U_0 and is allowed to develop while it traverses the duct of length L and height H. The top and bottom walls of the computational domain can be treated with no-slip ($u = 0$), no-penetration ($v = 0$) condition. On the right face, static pressure can be assumed to be zero along with other normal gradients.

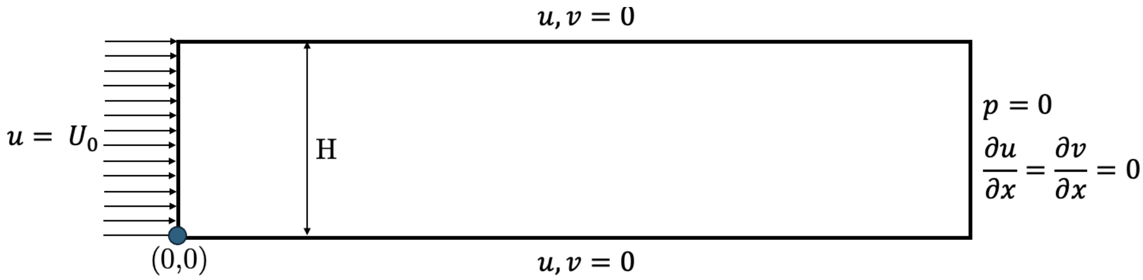

Figure 1: Schematic for lab 9.

Discretize the continuity and momentum equations under the steady-state assumption using the finite volume method and employ the SIMPLE algorithm for pressure-velocity coupling.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}$$

$$\rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = -\frac{\partial p}{\partial x} + \mu\nabla^2 u \tag{2}$$

$$\rho\left(u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}\right) = -\frac{\partial p}{\partial y} + \mu\nabla^2 v \tag{3}$$

Your code shall take L, H, N_x N_y, U_0 as user inputs. Compute the Reynolds number of the flow using the equation $Re = \frac{U_0 H}{\nu}$. The code shall produce:

1. The evolution of residual of continuity equation, $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$, summed over the entire domain as a function of the number of iterations.
2. Distribution of $u(x, y)$ through a contour plot. Choose a suitable colorbar to demonstrate flow development.
3. Distribution of $p(x, y)$ through a contour plot. Comment on the obtained plot.
4. Plot $u(y)$ vs. y at $x = \frac{L}{4}$, $x = \frac{L}{2}$ and $x = L$ on a single plot and compare these profiles with the fully-developed laminar flow solution. Comment on the obtained comparison.