APL 720: Lab 7

Submission deadline: 3rd April, 2025

Consider an incompressible, steady, two-dimensional flow between two parallel plates as shown in the figure below. The domain size is $L_x \times L_y = 3 \times 1$, where:

- At the inlet, a constant velocity, $u = U_{in}$ is imposed. Reynolds number based on U_{in} and L_y is $Re = \frac{U_{in} L_y}{\nu} = 50$. Consider water at room temperature as the working fluid.
- The top and bottom boundaries (walls) are stationary with a no-slip and no-penetration condition.
- At outlet, use a Neumann boundary condition for all velocity components $\frac{\partial u}{\partial x} = 0$, $\frac{\partial v}{\partial x} = 0$. Pressure can be considered as atmospheric i.e. presssure correction, $p' = 0$.

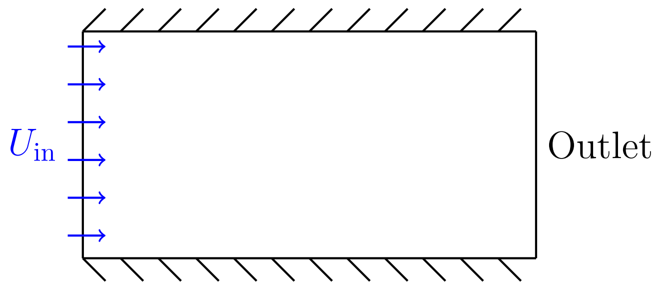

Figure 1: Problem schematic (not to scale).

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.

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

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \frac{1}{Re}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) \tag{2}$$

$$u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{\partial p}{\partial y} + \frac{1}{Re}\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) \tag{3}$$

Your code shall take N_x N_y as user inputs. 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 $u(x, y)$ and $p(x, y)$ through a contour plot. Choose a suitable colorbar to demonstrate flow development. Comment on the obtained plots.
3. Plot $u(y)$ vs. y at $x = \frac{L_x}{4}$, $x = \frac{L_x}{2}$ and $x = L_x$ on a single plot and compare these profiles with the fully-developed laminar flow solution. Comment on the obtained comparison.