APL720 - Computational Fluid Dynamics
Lab 5: Evaluation on February 13, 2025

Problem statement

Consider the domain of size $L_x \times L_y$ as shown in the schematic below. A Gaussian concentration profile of a pollutant is applied at the left boundary ($x = 0$). The rest of the domain initially contains no pollutant. A constant velocity field (u, v) is imposed on this domain along with assuming that a fluid with diffusion coefficient D fills the entire domain. Simulate how the pollutant spreads until a steady state is reached.

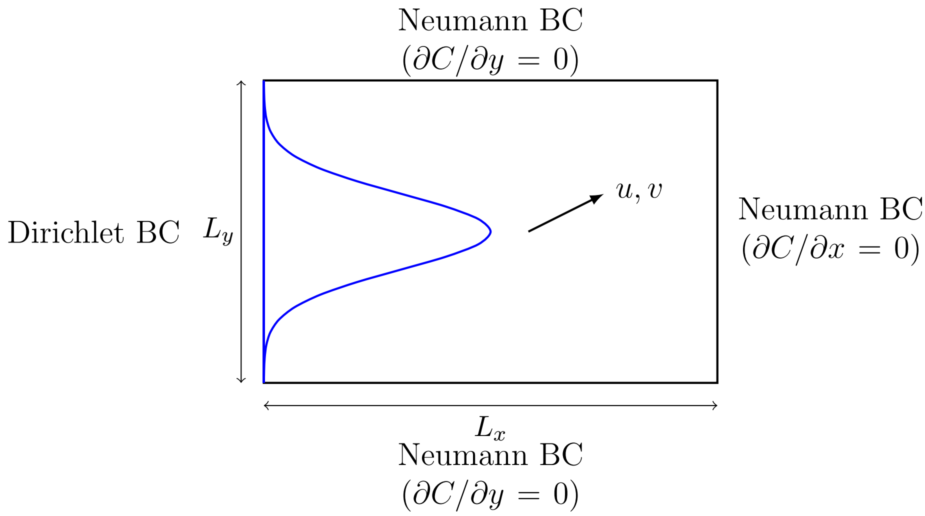


Figure 1: Schematic of the domain and boundary conditions with approximate Gaussian profile at the left boundary.

Governing equation

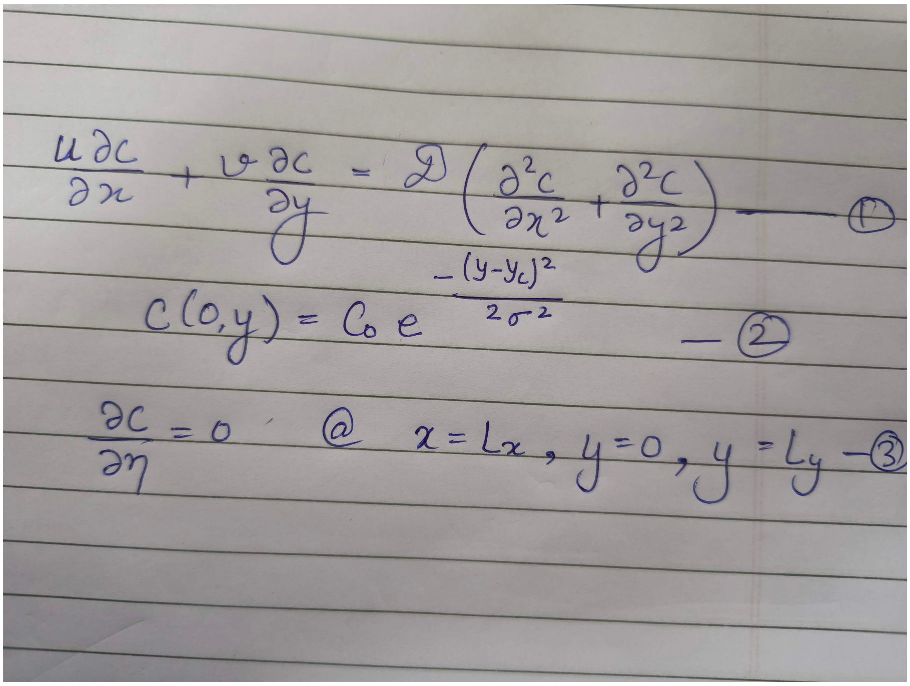
Solve the governing equation marked as (1).

Boundary conditions

- **Dirichlet condition at the left boundary ($x = 0$):** Use the second equation, where $C_0 = 1$ is the peak concentration, y_c is the midpoint along the y-axis, and σ controls the spread of the concentration and may be taken as $\sigma = \frac{L_y}{5}$.
- **Neumann conditions at other boundaries:** See the third equation.

Expected outcomes

1. Solve the governing equation using FVM with a central differencing scheme for discretization. Plot the steady-state concentration field as a contour plot. Inputs for



$$u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} = D\left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2}\right) \quad (1)$$

$$c(0,y) = C_0 e^{-\frac{(y-y_c)^2}{2\sigma^2}} \quad (2)$$

$$\frac{\partial c}{\partial \eta} = 0 \quad @ \quad x = L_x,\ y = 0,\ y = L_y \quad (3)$$

Figure 2: Equations used for this lab.

L_x, L_y, N_x, N_y, u, v and D will be provided at the time of evaluation. Compare the concentration profile obtained at the right boundary with that at the left boundary.

2. Solve the governing equation using FVM with a upwind scheme for discretization. Plot the steady-state concentration field as a contour plot. Compare the concentration profile at the right boundary obtained in part 1 with that to the upwind scheme.

3. Graphically demonstrate the stability of the concentration profile under the influence of varying parameters based on the discussion in the class.