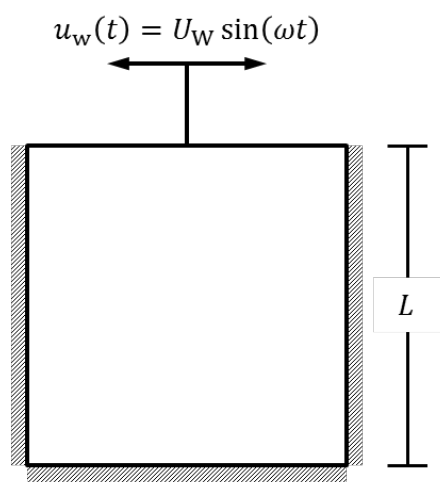
MAE/CSE 557
M.E. Mueller
Fall 2025

# MAE/CSE 557: Simulation and Modeling of Fluid Flows

## Mini-Project Three
## Due: December 1, 2025

*Directions: The compute portion of all assignments must be completed in a compiled language (C, C++, or Fortran) or another performant language (Julia). However, scripting languages can be used to manage a program as long the compute components are in a performant language, and any package including MATLAB may be used for making plots. Obviously, good programming practice (comments, etc.) are highly encouraged, and your source code must be submitted electronically with your write-up along with a readme with directions for compiling the code and running the program(s), preferably in a Linux environment (e.g., Nobel or Adroit). Your write-up should be typed and address all of the points for each problem and sub-problem, and you will need plots to support your discussion. The mini-project should be submitted by email to* muellerm@princeton.edu *and* israel.bonilla@princeton.edu *by 9:34am on the due date as a single tarball or zip archive. The filename should have the format "lastname_firstname.zip" (or .tar, .tar.gz, .tgz, etc.) and should contain a report in PDF format entitled "report.pdf", the readme file entitled "readme.txt", and the source code.*




Consider the flow inside a square with sides of length $L$ in which the left, bottom, and right walls are stationary and the top wall moves perpendicular to its normal with a sinusoidal velocity profile in time. Initially, the flow is stationary inside the box. The reference parameters for your flow are provided below:

$$L = 1\ [\mathrm{m}]$$
$$L\sqrt{\omega/2\nu} = 1$$
$$\mathrm{Re} = U_W L/\nu = 100$$
$$\gamma = 1.4$$
$$\mathrm{Ma} = U_W/a = 0.025$$

In order to compute the speed of sound, the pressure and temperature are 1 bar and 300 K, respectively, with a specific gas constant of 287 J/kg · K. The flow will be assumed to be isothermal.

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Your task will be to develop an incompressible flow solver utilizing the finite volume method for the flow inside the box by following the steps below. In your write-up, be sure to address all of the questions in the steps below and include any additional information as you see fit.

a. You are required to utilize a pressure-correction approach for solving the incompressible flow equations. Choose an appropriate pressure-correction algorithm for solving the incompressible flow equations. Justify your choice.

b. Choose appropriate finite volume operators for the volume and surface integrals in the integral form of governing equations. Justify your choices.

c. Choose appropriate temporal schemes and solution methods for your flow solver. Justify your choices.

d. For your choice of temporal schemes and spatial discretization, what are your expected (approximate) CFL limits?

e. Write your algorithm in pseudo-code.

f. Implement your approach. Prove that your implementation is correct by demonstrating expected convergence in both time and space.

g. Compare the solutions at $\omega t = 10$ for this incompressible flow solver and your compressible flow solver, at the various Mach numbers, from Mini-Project Two. Are there any differences between your solutions? At which Mach numbers do noticeable differences begin to appear? Ensure that your solutions are sufficiently accurate in time and space (i.e., grid-converged and time-converged). Note that an example code for Mini-Project Two will be available on Canvas if you prefer to use that to generate your compressible flow solutions for comparison.