Final Project - Due: Friday, April 26th at 11:59pm

- **The submission must be in the form of a report, i.e., it requires descriptive text and cannot just be a collection of result graphs and bullet point lists of methods, equations used. It should contain at the very least an abstract, sections on the governing equations, numerical methods, results, discussions and conclusion, and as an appendix, a printout of all functions you used to solve the project;**
- submit to Gradescope your final project report using the "Final Project" assignment and associate the pages/sections of your report with the relevant sections listed on Gradescope;
- submit to Gradescope **all** your source code files used to solve this project using the "Final Project Upload Code" assignment; this includes source code you uploaded previously to MatlabGrader;
- submit to Canvas any bonus problem movies using the "Final Project Upload Movies" assignment;
- In the Class Documents Module on Canvas you will find a list of functions you are not allowed to use in Matlab. Using these functions will be considered a violation of the Academic Integrity Policy.
- This project is cumulative. Sharing of code from prior assignments with other students will be considered a violation of the academic integrity policy. The same applies to using code from prior assignments from other students or sources outside the class;
- Shown point values are provisional;
- Bonus points do not carry over to other categories and the final project score is capped at 100%.

Assignment

You are tasked to model the flow in the two-dimensional rectangular mixing chamber of size $L_x = 3$ and $L_y = 2$ depicted in Fig. 1 using the non-dimensional continuity equation, 2D Navier-Stokes equations, and a convective/diffusive transport equation for the mass fraction Y of a chemical species with a Schmidt number of $Sc = 2$ (MAE561), respective $Sc = 1$ (AEE471). The chamber contains 2 chemical species absorbing rotating disks that are modeled using the Immersed Boundary method covered in class (the provided `clacSourceIBFinal.p` function). The fluid in the chamber with Reynolds number $Re = 100$ is initially at rest with zero mass fraction of the chemical species. At the initial time, inlets 1, 2, and 3 are opened, each issuing fluid with fully developed laminar channel velocity profiles (parabolic profiles) and composition as given in exam 7. All mixing chamber walls are no-slip and have zero flux of the chemical species. Note, these are the initial and boundary conditions from exams 5-7.

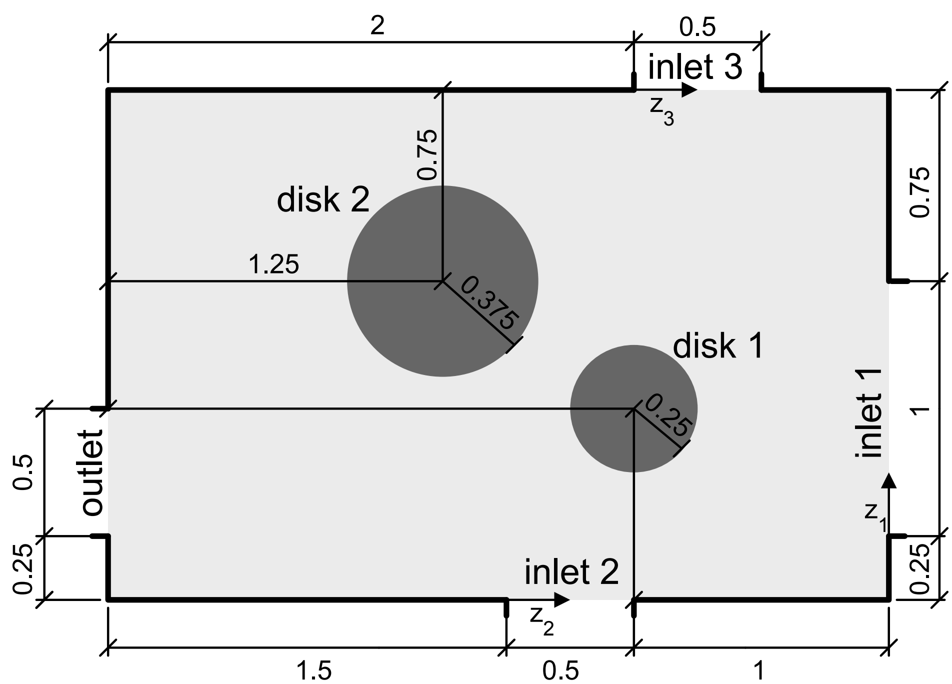

Figure 1: Mixing chamber geometry. The gray shaded area is the mixing chamber and the solution domain.

The performance of the mixing chamber shall be measured by the average kinetic energy $\bar{K}$ and mixing parameter $\bar{R}$ over the first 10 time units (these are the same metrics as in exam 7). You are tasked to find $\bar{K}$ and $\bar{R}$ with their error bars ($\pm x\%$) and visualize and discuss the flow field and mixing in the chamber.

Task 1 (124 points)
Write a **report** that must include at least

(a) all partial differential equations to solve the problem, boundary condition equations in analytical form (not finite difference form), equations to calculate all performance metrics in analytical form (not finite difference form);

(b) the names of all numerical methods used to solve the project and their formal order of accuracy; this must be presented in a table for the u, v, and Y equations in your report, see below table for an example format; state also the name of methods used to solve the Poisson equation and their spatial order as well as numerical methods to calculate the performance metrics and their order in space and time;

Numerical Methods and their Orders

	convective terms / elliptic terms				viscous/diffusive terms				boundary conditions	immersed boundary	variable location
	name time	order time	name space	order space	name time	order time	name space	order space	order space	order space	
u-equation											
v-equation											
Y-equation											

(c) finite difference equations of all numerical methods used **in sub-index form**, incl. all necessary stability constraints;

(d) mesh and time step sizes (CFL number) used to solve the project, and any other solution parameters used;

(e) the solution for the velocity components u, v, and mass fraction Y at $t = 4$, 4.25, 4.5, 4.75, 5, 5.25, 5.5, 5.75, and 6 time units and any other time units you deem important, plotted each as in prior exams;

(f) the time evolution of $k(t)$ and $S(t)$ for $0 \leq t \leq 10$ time units in separate graphs (see exam 7);

(g) the values of $\bar{K}$ and $\bar{R}$ with their error ranges ($\pm x\%$) separate from the supporting evidence that your answers are correct given in a solution verification table;

The submission must be in the form of a report, i.e., it requires descriptive text and cannot just be a collection of result graphs and bullet point lists of methods, equations used. It should contain at the very least an abstract, sections on the governing equations (see a), numerical methods (see b & c), results (see d - g), discussions and conclusion, and as an appendix, a printout of your script and all functions you used to solve the project. Make sure you select all appropriate pages for each section in your Gradescope submission. Review the posted provisional grading rubric to ensure you have all required components in your report.
MAE561 students must use the fractional step method with Adams-Bashforth/Crank Nicolson with ADI for the momentum equations and the WENO5-TVD-RK-3/Crank Nicolson with ADI method for the mass fraction equation. AEE471 students must use the fractional step method but can choose any spatial/temporal method, incl. FTCS.

Required submission:

☐ *final project report including all requested parts uploaded to Gradescope; the report must include at least an abstract, sections on the governing equations, numerical methods, results, discussions and conclusion, and as an appendix, a printout of your script and all functions you used to solve the project;*

☐ **all** *source code as *.m files used to solve this project uploaded to "Final Project Upload Code" on Gradescope;*

Bonus Task 1 (9 bonus points)
Make a movie of u, v, and Y for $0 \leq t \leq 10$ for task 1 and upload it to Canvas. Discuss the flow and mixing in the chamber visible in your movies. Indicate in your report's result section that you generated movies and uploaded them to Canvas.

Required submission:

☐ *in the results section discussion of flow and mixing visible in the movies and note that you uploaded movies;*

☐ *printout of any additional script and functions in the appendix;*

☐ **all** *source code as *.m files used to solve this project uploaded to "Final Project Upload Code" on Gradescope;*

☐ *all bonus part movie files uploaded to "Final Project Upload Movies" on Canvas.*

Bonus Task 2 (10 bonus points)
Redo problem 1 for a fluid with $Re = 200$ and $Sc = 3$ and include the results/solution verification/discussion in your report. As an AEE471 student, you will likely have to change the method used to calculate the mass fraction equation convective terms to make the calculation times feasible. If you do, include the new method's sub-index equations in your report.

Required submission:

☐ *In the results section solution verification, visualization and discussion of flow and mixing for $Re = 200$, $Sc = 3$;*

☐ **all** *source code as *.m files used to solve this project uploaded to "Final Project Upload Code" on Gradescope;*