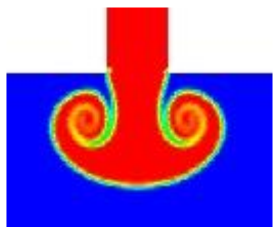
ACFD 2018 Project 3 discussion

Task 1

The results of Task 1a and 1b demonstrate the effect of surface tension in minimizing the area of water-air interface. The inter-molecular force of surface tension has an upward component that counters gravity, allowing the water drop to suspend and grow for an extended time. Task 1c produces a mushroom-cloud like structure for the fluid that's been injected into a chamber. This is typical when the two fluids have similar densities. In fact, the mushroom-cloud structure exists even for a single-phase flow (for example, injecting water into water.) The reference solution represents about the middle ground within the acceptable range of outcome. For Task 1c, more refined structures of the "coil" associated with the mushroom cloud can be simulated by refining the mesh and time step size. The following is an example (done by the instructor) of the contour plot at t = 1.5 s, using a global mesh resolution of 0.2 m then regionally refined over the quad bounded by (x,y) = (5,10) and (17,20). The time step size is 0.005 s, with max of 10 iterations per step.



Task 2

The simulation is straightforward as long as it uses a sufficient mesh resolution and a small enough time step size. See the reference solution. A common problem seen in some students' solutions is a significant loss of mass before the run reaches t = 0.2 s. This is likely due to an insufficient mesh resolution in the vertical direction (i.e., the direction normal to the slope). As the blob of glycerin becomes thinner over time, eventually the thin slab is represented by only one (or less than one!) grid point, which causes numerical errors.

Task 3

The period of oscillation is typically around 2.4 s, with t_1 = 0.6 s and t_2 = 1.8 s. This can vary somehow, depending on the detailed setup. For example, changing the mesh resolution would affect the viscous effect, which could slow down or speed up the oscillation.

For the calculation of water level in the left pipe, the feedback from students is that the outcome of the approach of "computing mass flux at a cross section of the pipe, then integrating mass flow rate in time" is somewhat sensitive to the setup. It's been reported that the computation could produce a water level at below -30 cm, as it shouldn't be. Indeed, this approach is less robust (compared to, for example, a direct volume integral of the mass of the left pipe), because it relies on using the information of the flow at a small cross section to infer the mass within a large domain. Moreover, since the cross-sectional area is small, it is covered by relatively few nodes of the mesh. The mesh may not be axially symmetric; An asymmetric mesh (see examples in reference solutions for Project 2) would produce a permanent bias in the mass flow rate. Due to irregularity of mesh in 3D, there might not be many (if any!) nodal points that are located on the cross section. This requires the system to perform additional interpolations – another source of errors. The errors would accumulate over time in the time integration. These errors could be alleviated by refining the mesh and time step size, and by averaging over many cross sections. A more robust approach is to setup integration over only part (e.g., the left half) of the system, then converting the total mass to water level.

For the additional exercise (for MAE598), combinations of boundary conditions that include “wall”, “velocity inlet”, or “outflow” would not work. Those boundary conditions allow either no traffic, or only one-way traffic, through the opening. When one or both openings are set to wall, ideally the system should not move at all. Nevertheless, slight initial movement of the system is reported in those cases before the system comes to a complete stop. This is likely due to the fact that initially the water levels in the pipes are not perfectly level, causing slight movement to adjust the water levels. (This movement is allowed. Recall that we ran the in-class demo of “dam break” with an “all-wall” boundary condition.) Many combinations of other types of boundary conditions work to produce the oscillation. To name a few:

• Any combinations of pressure inlet and pressure outlet (with zero gauge pressure for both)

• Combinations of “vent” or “fan” type of boundary conditions, with proper setup. Note that an “exhaust fan” with zero pressure jump is not too different from a pressure outlet with zero gauge pressure.