Introduction to Computational Multiphysics
Practical 5: The Riemann ghost fluid method.

In this practical we will implement a ghost fluid method capable of simulating a water-air interface. There are two parts to this practical; incorporating a water-air Riemann solver into your code, and implementing a (single-interface) Riemann problem-based ghost fluid method.

For a one-dimensional Riemann problem-based ghost fluid method, you need to identify the two cells either side of the interface, and use these as the initial states to solve the Riemann problem. The solution should then be copied to all appropriate cells. For example, if $\phi < 0$ corresponds to the region $x < x_I$, and this is material 1, then the left star state should be copied to all cells for material 1 where $\phi > 0$ and the right star state for material 2 where $\phi < 0$. This will use the mixed-material Riemann solver you developed for practical 1, though in this case, the only information you need from the solver are the two intermediate states, $\mathbf{u}_L^*$ and $\mathbf{u}_R^*$, wave positions and rarefaction structure are not needed.

Exercises:

When implementing the Riemann problem-based ghost fluid method, it will be useful to test some of the problems from practical 3 again, but with the new technique. You should now be able to get all five of Toro's tests working, as well as the air-helium shock tube test. Note that you can always use a stiffened gas as an ideal gas by setting $p_\infty = 0$.

The key test for this practical is a water-gas shock tube test from Chinnayya, Daniel and Saurel, "*Modelling detonation waves in heterogeneous energetic materials*", (2003), described in section 7.1 and plotted in figure 12. The initial data for this test is

$$(\rho, v, p)_1^T = \left(1000, 0, 10^9\right)^T, \quad \gamma_L = 4.4, p_{\infty,L} = 6 \times 10^8$$

$$(\rho, v, p)_2^T = \left(50, 0, 10^5\right)^T, \quad \gamma_R = 1.4, p_{\infty,R} = 0$$

Again, in the paper there is a typo in the initial pressure for the water region. For this test, the initial interface is at $x = 0.7$, with material 1 present in $x < 0.7$, and the final time is $t = 237.44\,\mu$s.

1. **Exact Riemann GFM**:
   Solve the water-gas shock tube test with the intermediate states calculated using your exact Riemann solver to provide boundary conditions for a Riemann problem-based ghost fluid method. For this, you will only need the intermediate states, the values in the rarefaction are not

required for these ghost fluid methods. Compare this solution to the results of your exact solver (and to the paper).

2. **HLLC-based Riemann GFM**:
Now replace the intermediate state from the exact solver with an approximate state from the HLLC approximate Riemann solver. How do results compare?