Project 3 discussion

General remarks

The transient simulations in this project are somewhat sensitive to the choices of mesh resolution (size of cell, Δx) and time step size (Δt), and we accept a relatively wide range of results. Nevertheless, for each task, the simulation should robustly produce the overall pattern of the flow and the timing of the sequence of key events. The reference solutions represent the range of results that are considered acceptable. Table 1 summarizes the resolution (Δx, Δt) used by the three Reference Solutions (Ref 1-3).

Task 1

Using Reference Solution #1 (Ref 1) as the benchmark, at t = 0.15 s the falling droplet evolves into a "teardrop" shape before hitting the water surface. Upon the impact, a crater is formed at t = 0.25 s and it deepened at t = 0.3 s. At t = 0.5, we see a hint of a smaller droplet bouncing back. The solution remains very similar with a slightly coarser mesh resolution in Reference Solution #2 (Ref 2). With a further coarsening of resolution but still a reasonable balance between Δx and Δt, Reference solution #3 (Ref 3) captures the timing of the events with coarsened flow patterns (e.g., one still sees a hint of the bouncing back of the droplet at t = 0.5 s), compared to Ref 1 and 2. (A comparison of the 2-D simulation with experiments is difficult, since in the 2-D case the droplet is actually a cylinder instead of a sphere.)

Task 2

The three reference solutions are of comparable resolution and they produce similar results. As a key feature, at t = 0.1 the leading edge of the blob of glycerin is detached from the surface. A simulation with a lower resolution in space and/or time would miss this feature. A common problem in many reports is that an unnecessarily large domain is used so as to sacrifice the resolution surrounding the blob. Note that the three reference solutions all use a relatively small domain with a shallow depth of the "box".

Task 3

Using Reference Solution #3 as the benchmark, the two cases exhibit the development of a "mushroom cloud" of the leaked methane. In Task 3a, the cloud ascends vertically. In Task 3b, it is blown downstream due to the imposed environmental flow. A distinctive feature in both cases is the formation of a vortex pair (the "swirls"), due to shearing after the initial formation of the methane jet. Figure 1 compares this feature (for the contour plot at t = 9 s for Task 3b) across the three reference solutions. With the highest resolution, Ref 3 (right panel) produces a clear swirl that wraps over several times. In Ref 1 (middle panel), with a reduced mesh resolution, the swirl is blurred. Ref 2 (left panel) has the same mesh resolution as Ref 2 but a coarsened time step size. As a result, the whole mushroom feature becomes slightly blurred. In some reports, the swirl is missing but replaced by small "air bubbles". This is a numerical error and indicative of the needs to adjust the resolution in space/time.

Task 4

See Ref 2 and Ref 3 for a typical solution. In some reports, turbulence model was not initialized using "default" (as instructed), and a different flow pattern was produced. We decide to still give credit to that version of solution.

Table 1 Mesh resolution (Δx) and time step size (Δt) used in the reference solutions

	Ref 1	Ref 2	Ref 3
Task 1	Δx = 2.5 mm Δt = 0.0005 s	Δx = 3 mm Δt = 0.0005 s	Δx = 5 mm Δt = 0.001 s
Task 2	Δx = 2 mm, with further local refinement Δt = 0.001 s	Δx = 4 mm, locally refined to 2 mm Δt = 0.001 s	Δx = 2 mm Δt = 0.001 s
Task 3	Δx = 0.5 m Δt = 0.01 s	Δx = 0.5 m Δt = 0.1 s	Δx = 0.35 m Δt = 0.01 s
Task 4	N/A (MAE494)	Δx = 2 mm Δt = 0.002 s	Δx = 2.5 mm Δt = 0.001 s

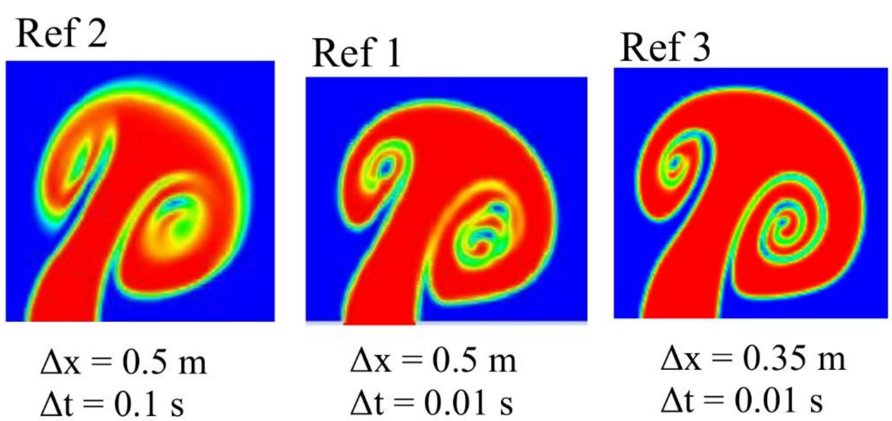

Fig. 1