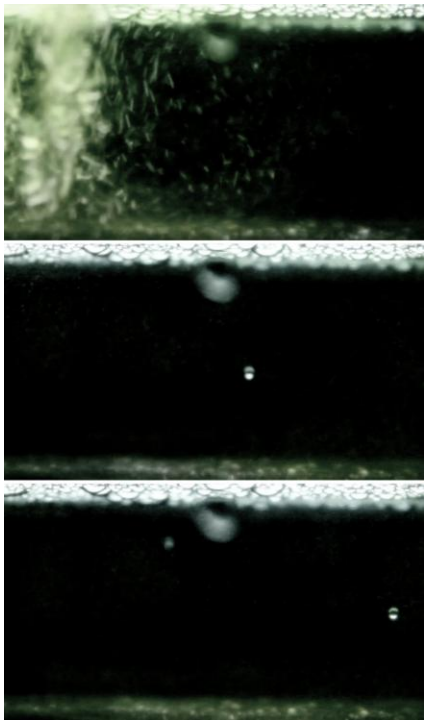


Team Second

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MCEN 5151 Flow Visualization 002

1 Context and Purpose

This 14.9 s video was shot for the Team Second assignment in MCEN 5151 Flow Visualization at the University of Colorado Boulder. The intent was to film antibubbles, liquid drops wrapped in a thin layer of gas inside a bulk liquid usually of the same composition [1]. They are rarely noticed because they are small, short lived, and easy to mistake for ordinary air bubbles. Scientifically, the goal was to show their motion within a bulk liquid. Visually, the goal was to highlight the antibubbles drifting slowly across a black background, filmed close enough that the thin air shell catches the light. Getting usable footage took several attempts; the rest of this report deals only with the final clip. No one else assisted with this video.

2 Experimental Setup

Figure 1 is a high-level sketch of the setup. A clear glass dish, 7 × 4 in (178 × 102 mm), sat on a dark towel and was filled with tap water mixed with Dawn dish soap. A plastic water bottle with a small hole poked in its cap was filled with the same soapy water, dyed with green and yellow dye, and loaded with a large amount of fine table salt. The bottle was squeezed by hand so that a thin stream struck the surface of the bath. A Canon EOS Rebel T100 rested on a folded dish towel on the counter, with the front of its lens 3.5 in (89 mm) from the side wall of the dish, looking horizontally through the glass. Filming took place at about 10:30 PM indoors in Manhattan Beach, California, roughly at sea level, at room temperature (taken as 70 °F, 21.1 °C). Figure 2 captures the three stages of flow that the video displays. All times t refer to the final video, which opens with a 2.7 s title card.

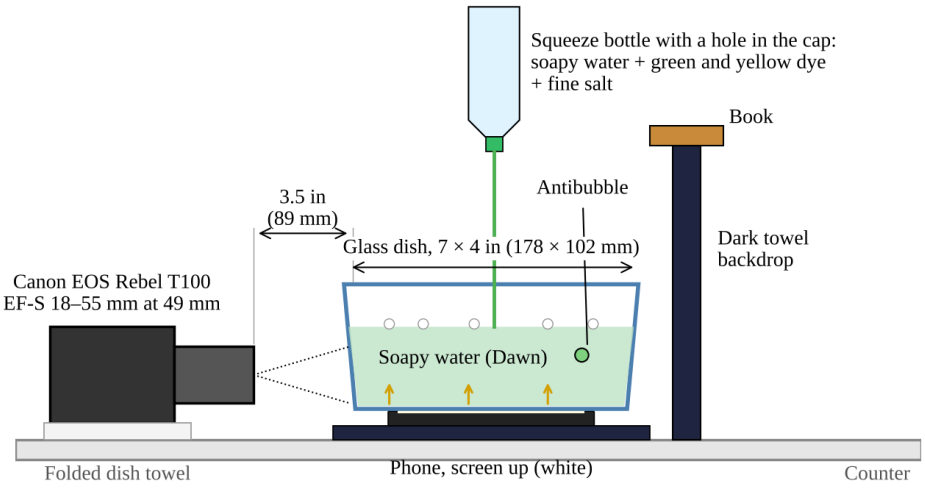


Figure 1. Side view of the setup (not to scale).

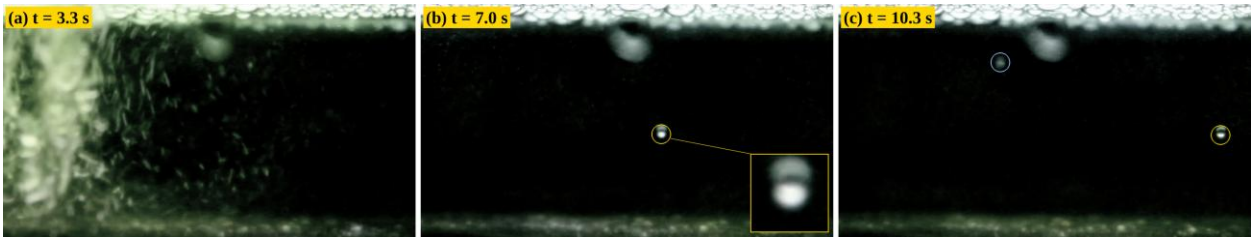


Figure 2. Frames from the video: (a) the dyed stream mixing into a turbulent plume, (b) the first antibubble drifting left, with a zoomed inset showing the bright caps on its air shell, and (c) the second antibubble (yellow ring) while the first fades out of focus (blue ring).

Stage 1, formation (t = 2.7 to 4.5 s). The dyed stream passes through the surface and drags a thin film of air down with it. Dorbolo et al. [2] describe a similar process when soapy water is gently poured onto a bath of the same liquid: the incoming liquid forms a streamer coated in air, which breaks up into globules through the Rayleigh Plateau instability, and each globule that keeps its coat of air becomes an antibubble. The soap coats both faces of the air film with a layer of surfactant [2], which keeps it from rupturing right away. In Fig. 2a most of the stream has simply mixed into a turbulent green plume, and only a few antibubbles survive it.

Stage 2, drift (t = 4.5 to 9.5 s). The first antibubble enters from the right at t = 4.5 s and drifts left across the frame in Fig. 2b. Tracked frame by frame in the original clip, using the image scale derived in Section 4, it is about 30 px across, or d ≈ 1.15 mm (0.045 in). Between t = 5.0 and 9.0 s it moves at an average speed of U ≈ 7.4 mm/s (0.29 in/s) relative to the dish, mostly sideways, while rising only about 2.0 mm/s (0.08 in/s). Using its diameter as the length scale and the kinematic viscosity of water at 70 °F [3], since the soap is a small fraction of the bath, the Reynolds number [4] is

$$\mathrm{Re}=\frac{Ud}{\nu}=\frac{(7.4\ \mathrm{mm/s})(1.15\ \mathrm{mm})}{(0.98\ mm^2/\mathrm{s})}\approx 9 \qquad (1)$$

so inertial and viscous forces are of the same order. U is measured relative to the dish; relative to the water, the antibubble likely moves closer to its 2 mm/s rise, which gives Re ≈ 2. These estimated Reynolds numbers are consistent with laminar flow around the antibubble. The slow rise is also consistent with the antibubble being mostly liquid.

Its air shell is very thin (about e ≈ 3 μm according to Dorbolo et al. [2]) so the fraction of its volume that is air, the shell's volume divided by the sphere's volume, is

$$\varphi \approx \frac{4\pi r^2 e}{\frac{4}{3}\pi r^3} = \frac{3e}{r} = \frac{6e}{d} = \frac{6(0.003\text{ mm})}{1.15\text{ mm}} \approx 0.016 \quad (2)$$

Thus for an inner liquid with the same density as the bath, the net upward force would be about 1.6% of that on an air bubble of the same external volume. Added salt increases the core density and reduces this force further. Dorbolo et al. [2] add salt for exactly this reason, to counterbalance the buoyancy and slow the rising motion, and note that with the right amount an antibubble floats in place. The slow rise is consistent with the salt partially offsetting the net upward force, although local water motion also affects the observed trajectory.

Stage 3, leaving the focal plane (t = 9.5 to 14.9 s). A second antibubble enters from the right at t = 9.5 s and follows a similar path, moving at about 5.1 mm/s (0.20 in/s) and again rising about 1.8 mm/s, or 0.07 in/s in Fig. 2c. Meanwhile the first antibubble turns, drifts slightly downward with the current, and blurs as it leaves the thin plane of focus. Both fade out this way rather than popping. Antibubbles last from a few seconds to a few minutes [1]. When one does die, the air in the shell drains from the bottom toward the top, and the film ruptures at the bottom, where it is thinnest [1]. A pierced antibubble collapses in less than 50 ms [5], too fast to resolve in detail at 29.97 fps.

3 Visualization Technique

No seed particles were added. The dye marks the incoming stream and the plume in Stage 1, while the antibubbles themselves are visible only because their curved air shell bends and reflects light, which shows up as a bright cap on the top and bottom of each one. The only light on the dish came from one smartphone placed directly against the underside of the glass, screen up, showing a plain white screen at an estimated 1000 nits. It sat roughly 3 in (77 mm) below the antibubbles. Because the light travels upward while the camera looks horizontally, very little of it enters the lens directly. This dark field lighting makes the antibubble shells and surface foam stand out against the dark bath by directing light into the camera through reflection, refraction, and scattering. Additionally, navy blue towels draped behind and around the dish blocked ambient light and further darkened the background.

4 Photographic Technique

The camera was a Canon EOS Rebel T100 digital SLR resting on a folded dish towel, recording 1920 × 1080 px video at 29.97 fps; the original clip is 24.96 s long (748 frames). The lens was a Canon EF-S 18–55 mm f/3.5–5.6 III set to 49 mm and focused manually, with the aperture at f/5.7 (as recorded in the file metadata) and its front 3.5 in (89 mm) from the dish. The camera recorded a focus distance of 0.25 m (9.8 in) from the sensor, which is this lens's closest focusing distance, where its rated maximum magnification is 0.34 [6]. Taking that rating to apply at the long end of the zoom (55 mm), the magnification at 49 mm is scaled with focal length,

$$m \approx 0.34\left(\frac{49\text{ mm}}{55\text{ mm}}\right) \approx 0.30 \quad (3)$$

and, assuming the 16:9 video frame spans the full 22.3 mm width of the sensor, the field of view is

$$W = \frac{w_s}{m} = \frac{22.3\text{ mm}}{0.30} \approx 74\text{ mm} \quad (4)$$

or 2.9 in across. The image scale is therefore 1920 px / 74 mm ≈ 26 px/mm, so each pixel spans about 0.04 mm (38 μm). After cropping, the final frame spans about 56 × 31 mm (2.2 × 1.2 in). The camera ran in automatic movie exposure (Program AE) with Auto ISO and automatic white balance; the T100

records zero for shutter speed and ISO in its movie files, so neither can be reported. The exposure of each frame can be no longer than the interval between frames,

$$\Delta t = \frac{1}{29.97 \text{ fps}} \approx 0.0334 \text{ s} \tag{5}$$

and in that time the first antibubble, moving at U from Stage 2, travels

$$\Delta x = U\Delta t = (7.4 \text{ mm/s})(0.0334 \text{ s}) \approx 0.25 \text{ mm } (0.0097 \text{ in}) \tag{6}$$

or about 6 px, a fifth of its own diameter, so its path is easily tracked from frame to frame. The antibubble spans about 30 px, enough to show its outline and the two bright caps, but the 3 μm shell is less than a tenth of one pixel and is seen only through the light it bends. At this close distance the depth of field is also thin, which is why the antibubbles blur as they drift toward or away from the camera.

Post-processing was done in iMovie. The clip was trimmed to 12.18 s (6.34 to 18.52 s of the original) at unchanged speed, and a 2.74 s title card was added at the start. The frame was cropped to a 1454 × 818 px region at the upper right of the original, which removes the brightly lit bottom of the dish, and scaled back to 1920 × 1080 px. In the color-correction panel, the shadows were pulled down until the bath turned nearly black, and the saturation was lowered so the antibubbles stand out. Figure 3 compares one frame before and after editing. The final video is 1920 × 1080 px at 29.97 fps, played back at the capture rate (real time), and 14.9 s long.

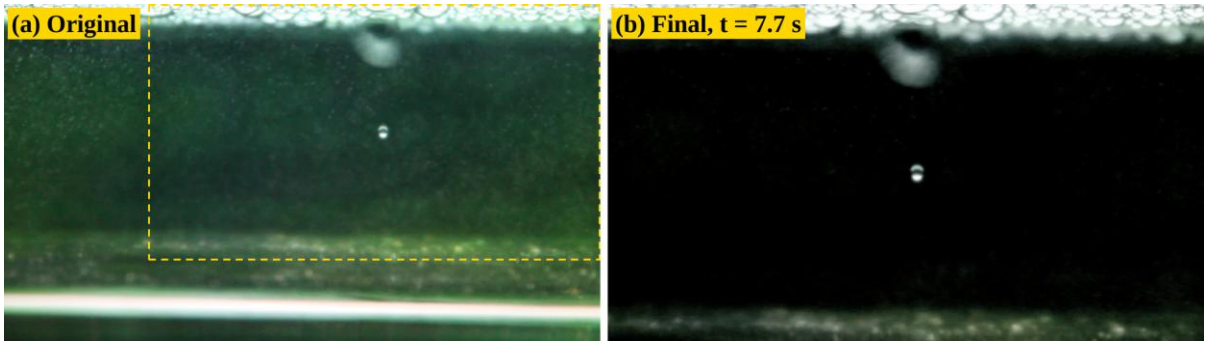


Figure 3. The same instant (a) in the original frame, with the dashed box marking the region kept by the crop, and (b) in the final video after cropping and color correction.

5 Video Dissection

The video captures how antibubbles are born from a pouring stream and how differently they move from air bubbles: instead of racing to the surface, they drift sideways with the leftover currents and rise only about 2 mm/s. Both the scientific and the visual goals were met. The strongest part is Stage 2, where a single bright antibubble drifts across a black background and the two caps of light from its air shell are visible. The main weaknesses are that the antibubbles are small in the frame, the image is soft and slightly noisy, a large ordinary air bubble stuck under the surface foam sits at the top of every frame, and the formation itself happens inside the plume, where it cannot be seen. It is also unclear how many antibubbles formed in total, since most of them likely popped or left the plane of focus during the pour.

The analysis rests on the following assumptions. (1) The magnification at 49 mm scales from the rated 0.34, taken to apply at 55 mm, and the frame spans the full sensor width, so the sizes and speeds are estimates. (2) The antibubble diameter is read to about ±5 px (±0.2 mm) because its edge is blurred. (3) The bath has the viscosity of water at 70 °F, since the soap fraction is small. (4) The air shell is about 3 μm thick, as measured by Dorbolo et al. [2]. (5) Refraction through the glass wall and water is ignored when computing the field of view. (6) The phone screen's brightness is an estimate.

Natural next steps are to add salt in measured amounts to find the point where an antibubble hovers in place, use an undyed bath with a dyed core so the liquid inside the shell can be seen, and film at a higher frame rate to capture an antibubble popping.

6 References

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[3] The Engineering ToolBox, "Water - Dynamic and Kinematic Viscosity at Various Temperatures and Pressures." engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html (accessed Oct. 28, 2026).

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[7] Anthropic, "Claude AI," claude.ai (accessed Oct. 28, 2026). Used as an AI assistance tool to generate the figures and to assist with phrasing and organization of the report.