

Team First Report

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Flow Visualization, Section: 5151

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This is the first team assignment of the 2026 fall semester. All the images and videos captured were done with assistance from Alex Osten and Rylan Hodgson. Alex Osten operated the lighting and Rylan Hodgson operated the Phantom v2012 camera, while I released the drops. The goal of this flow visualization was to capture the effect where water droplets persist on the surface of water, and more specifically, capture in detail the period where the drops reform with the larger body of water. We wanted to show the viewer the minute details that would be hard or impossible to see by eye, utilizing the high speed camera and macro lens. We originally had difficulty getting the droplets to persist for any reasonable amount of time, and eventually became aware that lowering the surface tension of the water by adding a small amount of soap helped get the shot we were looking for. We chose a video instead of a still because we found that it allowed for a greater understanding of the flow that was present, as well as added artistic value.

Due to our choice of macro lens and lighting needs, it was beneficial for us to use the smallest beaker available to us. We settled on a beaker about 2 in in diameter with water depth of about 3 in. The water was dropped from a pipette, with special care taken to ensure they fell as single drops, which can be seen in Figure 1. They were dropped from an approximate height of 3/8 in, which was discovered to leave the best drops after some experimenting. The drops that were captured in this submission were roughly 1/8 in in diameter, but varied in size while experimenting. The drops were controlled only by squeezing the pipette, which definitely contributed to drop size differences. The flow that was visualized was initially a small drop of water gaining enough mass to overcome the tension forces holding it onto the pipette tip, which then falls toward the surface of the reservoir. Once contact is made with the reservoir surface, the drop immediately flattens as it transfers its momentum to the surrounding water, dimpling the water, and causing a small radial wave to form (Figure 2). The drop soon recovers its circular form and persists momentarily, as the wave damps out due to frictional forces. Finally, the drop and the reservoir combine at a small point near the bottom of the drop with the contact area steadily growing until the drop is absorbed fully.

Duchemin & Josserand (2020) modeled how the thin air film trapped beneath a drop drains before coalescence, and found that drainage is faster over a liquid surface than over a solid one. Klyuzhin et al. (2010) measured how long drops persisted on a water surface while slowly lowering the surrounding air pressure. Although residence times decreased as the pressure dropped, some long-lasting drops were still seen at very low pressures, which led the authors to propose that structured interfacial layers, rather than a trapped air cushion alone, might explain the phenomenon.

Taken together, these studies suggest that the phenomenon, although readily replicable, is not fully understood. It is tough to tell from watching the video what is causing the effect, so it is tough to definitively claim any reasons.

Impact velocity, assuming free fall from a height 0.009525m (3/8 in) and neglecting air drag:

$$U = \sqrt{2gH} = \sqrt{2(9.81 \text{ m s}^{-2})(0.009525 \text{ m})} = 0.432 \text{ m s}^{-1} \quad (1)$$

We chose to analyze the Weber number (also suggested by our guest) because it is the most relevant dimensionless group for this flow, and because surface tension controls the shape of the drop and the ripples it makes.

Because we added soap to the water, the surface tension of our water was lower than that of clean water, which is about 0.073 N m^{-1} near room temperature ([The Editors of Encyclopaedia Britannica, 2026](#)). We did not measure the new surface tension, which the soap lowers, so we assumed the clean-water value. Weber number, comparing inertia to surface tension:

$$We = \frac{\rho U^2 D}{\sigma} = \frac{(998 \text{ kg m}^{-3})(0.432 \text{ m s}^{-1})^2(0.0032 \text{ m})}{0.0728 \text{ N m}^{-1}} \approx 8 \quad (2)$$

A Weber number of around 8 means that the inertial and surface tension forces are comparable. We will begin to see drop deformation, but cohesive forces are still able to prevent drop breakup. Interestingly, this description matches very closely to what can be seen in the video.

To help the drops persist on the surface, a few drops of hand soap were added to the water in the beaker, which lowers the surface tension of the water. The water was approximately room temperature, and was collected from the tap. We did not measure the resulting surface tension or investigate how the soap changes coalescence, so its complete effect other than visually longer persistence is not fully known. The drop was visible purely from reflections and refractions in the reservoir and in the drop itself, so no additional dyes or technique were needed to enhance the flow. This setup was lit from behind with a large LED panel and across with a very powerful spotlight. The high speed setup needs a lot of light to be exposed properly.

The video was shot on a Phantom v2012 high-speed camera, whose monochrome sensor is why the footage is black and white. It was recorded at 4000 frames per second with a $240 \mu\text{s}$ exposure and a resolution of 1280×800 pixels, using an AF 180 mm f/3.5 macro lens, and we neglected to record f-number for this particular shot. Playback is at 30 frames per second, so the motion is slowed by a factor of about $4000/30 \approx 133$. The lens was approximately 6 in from the reservoir surface. The footage was edited in iMovie, where I added the title card. The final exported video is 1920×1080 pixels and 28.7 seconds long, including the title.

I really like that the video reveals flow that I would not have been able to see with my naked eye. We did not really investigate how adding soap altered coalescence, which would be a natural next experiment, for example by comparing drops on clean water with drops on water of a measured soap amount. I think we did fulfill our intent, but I do think the video would have benefited if we were able to achieve a better meniscus on top of the beaker to drop into.

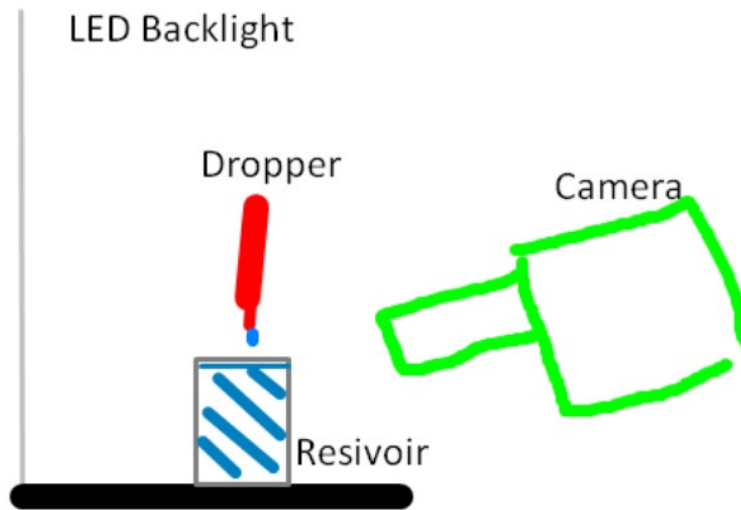


Figure 1: Apparatus sketch: visible are the LED backlight, water, pipette, and camera. A spotlight (not drawn) lit the scene from the side.

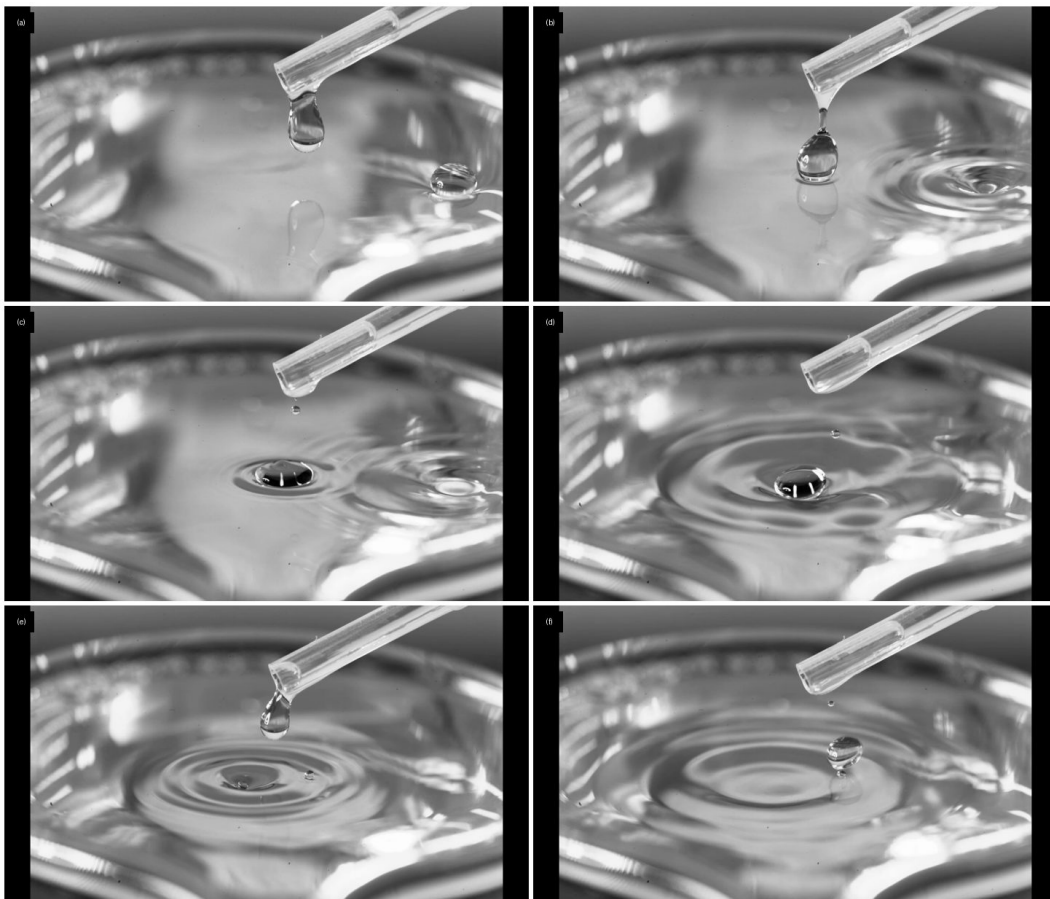


Figure 2: Frames from the video. (a) Drop Beginning its Descent (b) Drop Contacts Water (c) Drop Flattens and Wave Begins (d) Drop has Stabilized (e) Second Drop Begins to Fall (f) Second Drop Coalesces.

References

- Duchemin, L., & Josserand, C. (2020). Dimple drainage before the coalescence of a droplet deposited on a smooth substrate. *arXiv preprint* arXiv:2004.12365. Retrieved from <https://arxiv.org/abs/2004.12365>.
- The Editors of Encyclopaedia Britannica. (2026). *Surface tension*. Encyclopaedia Britannica. Retrieved from <https://www.britannica.com/science/surface-tension>.
- Klyuzhin, I. S., Ienna, F., Roeder, B., Wexler, A., & Pollack, G. H. (2010). Persisting water droplets on water surfaces. *Journal of Physical Chemistry B*, 114(44), 14020–14027. doi:10.1021/jp106899k.