Team First Report: Deforming Bubbles

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2025 Get Wet
MCEN 5151
10-03-2025

Introduction: This video was created for the 2025 Team First assignment, the second project in the Flow Visualization course at CU Boulder. The intent of this project was to demonstrate the limits of tension forces in fluid. The spatially varying tension was visualized with the use of roughly 2 feet tall bubbles made from a custom solution. During the process of creating this image, 69 different shots of the various bubble structures at different moments in time were captured, with the final image being chosen for the best demonstration of the underlying physics.

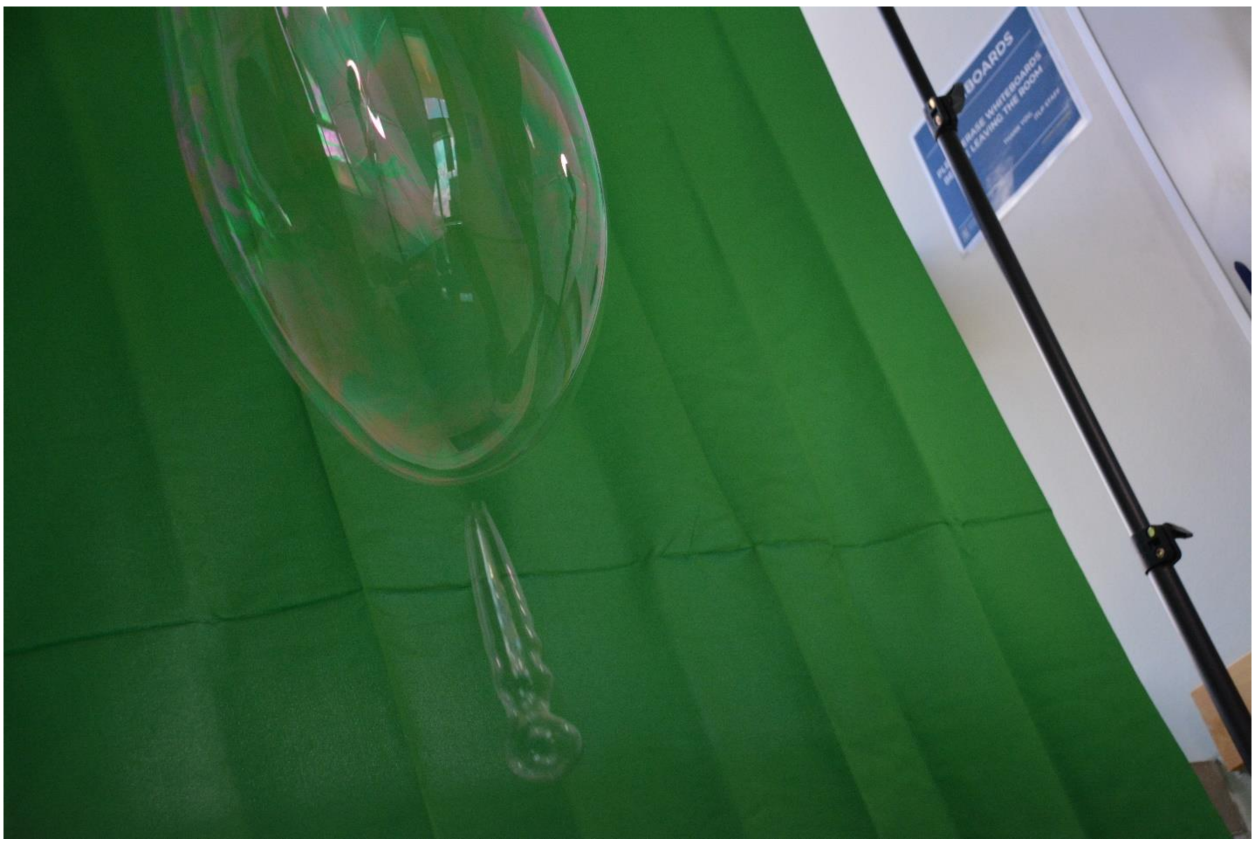
Flow Discussion: The bubble in the image was created using a custom bubble wand made from plastic straws and string. The bubble wand was dipped into a solution and then pulled out at varying rates of speed and angles to create shapes like the final piece. One group member would consistently dip and pull the wand out, while another would photograph the created fluid structures.

The extensional rheology of the bubble solution is the most important factor in creating a bubble (Frazier et. al 2020). The Bond number can be used to estimate the maximum size of a bubble created by soap-based solutions supported solely by surface tension forces (eq.). The bond number provides a ratio of gravitational forces to surface tension forces. If the force of gravity exceeds the surface tension, then the bubble will separate until it achieves a better balance as shown in the capture photo. The ejecta from the bubble is the fluid shedding its excess until surface tension once again dominates the main structure.

[1] $$Bo = \frac{\rho g z R_b}{\sigma}, R_b = radius\ of\ bubble, z = film\ thickness, \rho = liquid\ density, \sigma = surface\ tension, g = acceleration\ due\ to\ gravity$$

The sheen on the bubble is caused by interference patterns from the lighting sources of the photography setup (Tompkins 2014). The light reflects off both the outer and inner surface of the soap bubbles, leading to the enhancement of some wavelengths and the diminishing of others. The balance between gravitational effects and surface tension on the bubble leads to uneven thickness in some areas, further varying the possible band of colors on its surface.

Visualization and Photographic Technique: The custom bubble solution was roughly 2 cups of distilled water, ¼ cup of Dawn dish soap, a tablespoon of glycerin, and a teaspoon of gel food dye. These values were used to get a solution that made "stable" bubbles that could hold their shape for longer periods of time as they were stretched out to size between 1-2ft. The solution was mixed in an aluminum baking pan, and an unspecified amount of both red and blue dye were added to provide color to the fluid structures. A colored curtain was set up to provide a background to the image, and the aluminum baking tin was placed in front of the background, about 8 inches from the curtain. The aluminum tin was raised on a cardboard box so that bubble creation started at a higher point, allowing the fluid structures to reach a greater height before popping. This allowed for more optimal angled placements of the tripod. The room had a window that encompassed most of the wall on the east side of the room, which was left cracked open. We believe that slight airflow through the window could have influenced the stability of bubbles as well.



For the photographing session, we had reserved a 2-hour time slot in a study room on the 2nd floor of the Drescher Undergraduate Engineering ITLL Building on CU Boulder's main campus. The window on the east side provided natural light that diffused from behind the curtain setup for the image. Two 23 watt LED lamps were used to light the setup from the front to brighten the image at the fast shutter speeds needed to capture these structures. The camera used was a Nikon D5200 with and 18 – 135mm zoom lens. The focal length for the captured image was 35mm. The f number was f/4.5, shutter speed was 1/400 sec, and ISO was 1600. The original image with and height is 6000 x 4000 pixels, with the final image cropped and rotated so that it is 477 x 900 pixels. Further processing was done by altering the rgb curve to further highlight the curve of the bubble from the green background.

Conclusion: This image reveals the constant balancing of gravity and tension in these bubble fluid structures, and how the structure achieves greater balance between the two forces by splitting itself. I dislike that the creases of the background are still visible in the final image, and I believe the image quality could've been significantly sharper as well. I do like how the color editing made certain features of the image stand out, however. I would like to improve the repeatability of creating specific structures, if possible, rather than hoping by chance to get one that demonstrates physics in an extreme way. I think this idea could potentially be automated, or a tool developed, that would essentially keep the bubble wand on a fixed rail and allow for a more uniform direction and speed when creating these bubbles.

References:

Frazier, Stephen, Xinyi Jiang, and Justin C. Burton. 2020. "How to Make a Giant Bubble." Physical Review Fluids 5 (1): 013304. https://doi.org/10.1103/PhysRevFluids.5.013304.

"Understanding Interference Patterns in Soap Films - Eric Tompkins." n.d. Accessed March 18, 2014. http://laser.physics.sunysb.edu/~ett/report/.