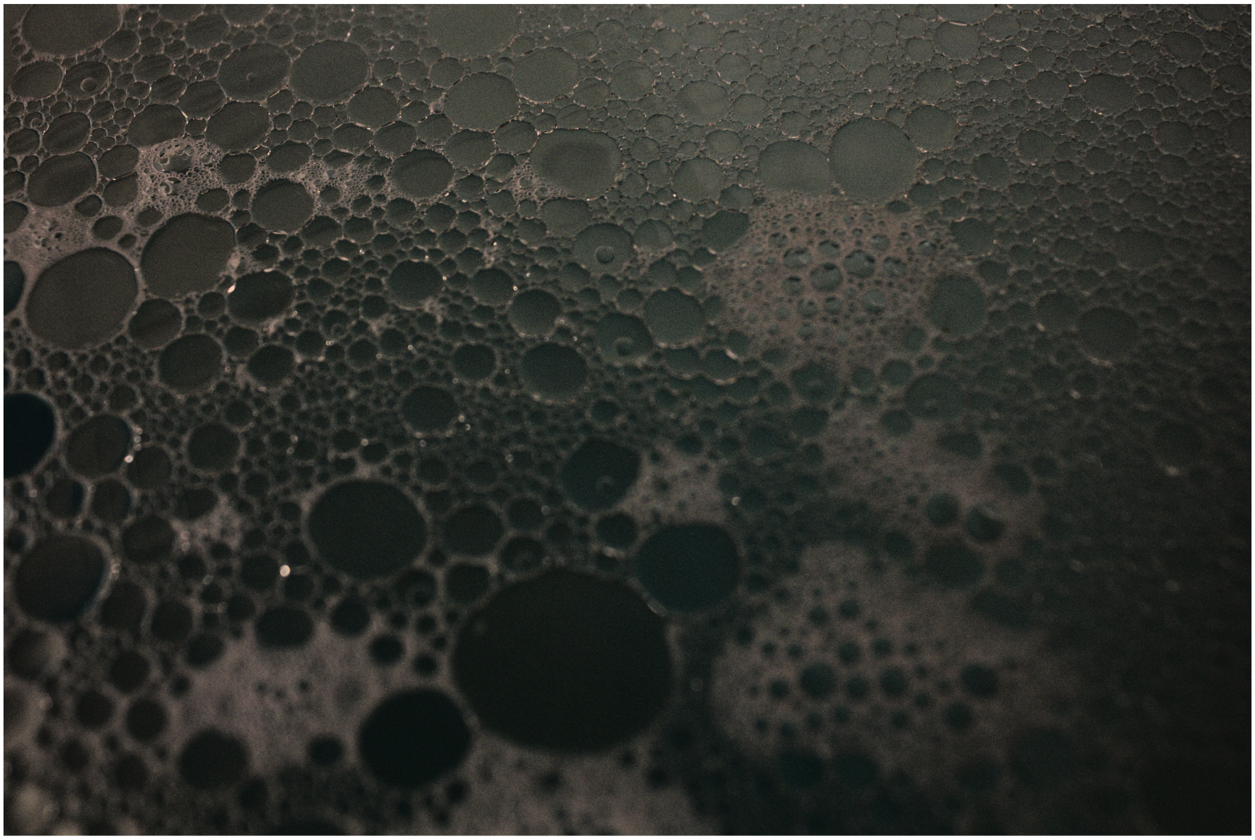
# Get Wet/Vis 1 Report
Flow Visualization
Nathan Gallagher



## I. Introduction

The goal of this image was to learn the basics of fluid photography, visualize an interesting flow phenomenon, and to get used to operating a camera that was more complex than a cell phone. The initial goal of this experiment was to visualize dish soap falling through water, but I was unable to produce an interesting image of the flow. After that experiment was completed, I noticed that a number of interesting bubble patterns had formed on top of the water, which is what led to me capturing the final image.

## II. Testing Setup and Materials

The test apparatus consisted of a large tub of water with a number of other fluids added into it. The tub was stirred slightly and then allowed to settle while the different fluids formed bubbles on top. After 10 minutes had passed, the surface of the tub was photographed. Figure 1 shows a graphic of this setup.

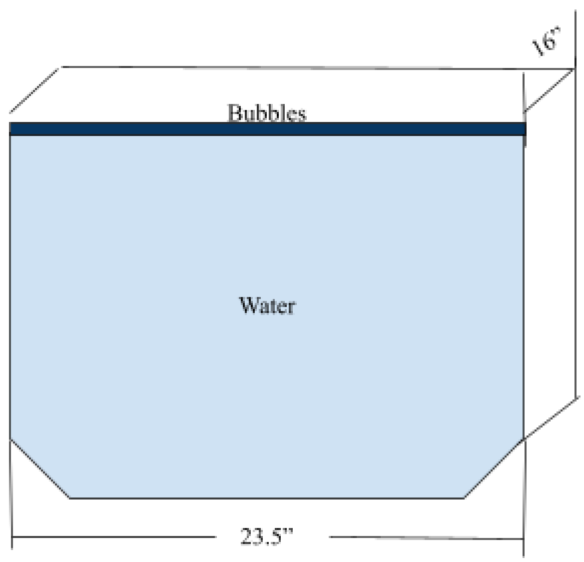



Figure 1: Experimental Setup.

Two fluids were added to the tub before bubbles were allowed to form, dish soap and olive oil. The brands I used in this particular experiment are shown in Figure 2.



Figure 2: Fluids added to the tub

Due to the spontaneity of this portion of the experiment, the exact amounts of fluid in the bin at the time the photograph was taken, so if one were to recreate this experiment I would recommend slowly adding fluid and observing the bubbles until they reach the desired consistency. While doing this, ensure that there is always more dish soap in the bin than olive oil.

## III. Physics Analysis

There are a few physics phenomena at work in this image. First, the surface tension of the various fluids in the tub allow bubbles to form and rise. Second, the differences in density of the different fluids allow for the lighter fluids to sit on top of the water without sinking. Finally, we can see the formation of a soap film between the variety of different bubble formations.

### A. Surface Tension

Surface tension is the phenomenon that is allowing the bubbles on the surface of the water to hold together instead of simply flattening into their respective liquids. Surface tension is the name given to the combination of intermolecular forces of the soap particles pulling on each other. When these intermolecular forces are acting on other molecules of the same fluid, they are called cohesive forces. When they are acting on molecules of a different fluid, they are called adhesive forces. A bubble can remain stable if the forces acting on its walls are balanced. These forces can be visualized via the drawing in Figure 3:

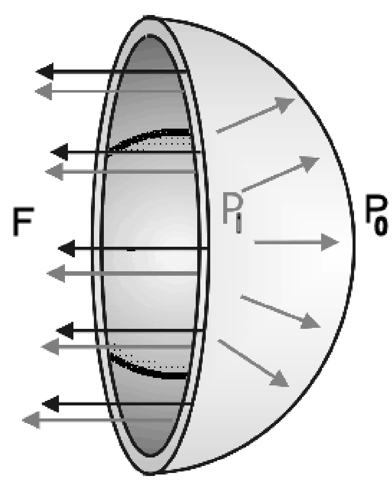



Figure 3: forces acting on a hemispherical bubble (Labman Physics, n.d.)

For the bubble to be stable, the cohesive forces holding the soap molecules together must match the force created by the pressure gradient between the air inside the bubble and the air outside the bubble. This balance, for a spherical bubble, is demonstrated by Laplace's Law (Labman Physics, n.d.),

$$P_i - P_o = 2\gamma/r.$$

In this equation, Pi is the inside pressure, Po is the outside pressure, $\gamma$ is the surface tension between molecules, and r is the radius of the bubble. We can see from this equation that if the pressure on either side of the membrane were to change, then the equation would become unbalanced and the bubble would pop. It is thanks to this balance between the surface tension and the pressure gradient that allows the bubble to continue to exist.

**B. Density**

The image shows that the fluids in the tub are clearly laying in layers on top of eachother. This happens due to a difference in density between the four fluids. Density is a measure of the weight of a fluid divided by its volume. By normalizing by the volume, density allows us to compare the “weight” of different fluids without needing to account for how much of the fluid exists. This is important, because a more dense fluid will tend to sink into a less dense fluid (Lumen Learning, n.d.). Table 1 shows the estimated densities of the four fluids in this experiment (Mater Christi School, 2015).

Table 1: Experiment Fluid Densities

| Fluid | Density (kg/m^3) |
|---|---|
| Water | 997 |
| Olive Oil | 920 |
| Dish Soap | 1030 |

As the table shows, we would expect the olive oil to float on top of the water, but the dish soap to sink to the bottom. We see that the olive oil is indeed forming clusters on top of the water, but we also see soap on top of the water. This is likely because the soap has been shaken enough to form a foam, which is allowing it to float on the water.

**C. Formation of Soap Foams**

When the soap was initially added to the water, a number of air molecules were trapped inside of bubbles held together by the surface tension of the water and soap mix. Typically, these bubbles would quickly burst thanks to the tendency of water molecules to pull strongly on one another. This interaction would typically draw the water molecules making up the bubble back down into the main body of the water. This is an illustration of the surface tension forces discussed earlier being more powerful than the pressure differential across the bubble wall. However, dish soap is a surfactant, meaning that it reduces the surface tension of the fluid that it has been mixed with (MIT, n.d.). If the surface tension of the water is reduced, then the bubbles become more stable and the pressure differential can more readily counteract the powers of surface tension. As this thin bubble film is not broken, the air inside continues to pull upwards on the bubble, which in turn allows it to sit on top of the water alongside the olive oil. It doesn't float away thanks to the surface tension pulling downwards, and it doesn't sink thanks to the dish soap weakening that same surface tension.

## IV. Photographic Technique and Post-Processing

This image was taken in my bathroom at home by a Canon EOS REBEL T2i. The camera specifications are shown in Table 2 below.

Table 2: Camera Specifications

| Specification | Value |
|---|---|
| Focal Length | 25 mm |
| ISO | 1600 |
| f-stop | f/5.0 |
| Shutter Speed | 1/50 |

The camera was 2-5 inches away from the surface, and the image was taken after the bubbles on top of the water were no longer changing visibly. The image was lit using an array of 5 warm-colored light bulbs positioned about 5 feet above and behind the tub. This lightning setup did not produce much light, which produced a fairly dark, monochrome image. The image was finalized in Darktable. Figure 4 shows the raw image before any edits were made.

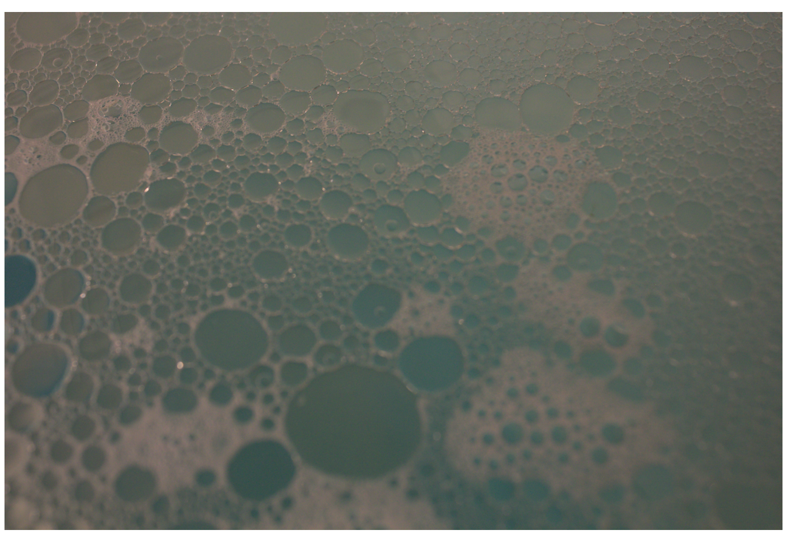


Figure 4: Raw image

Once the image was brought into Darktable, a few adjustments were made to enhance the sharpness of the image and accentuate the shadows in the image. This was primarily achieved by applying an rgb S-curve that more evenly distributed the mid whites across the entire white spectrum. This resulted in the following final image:

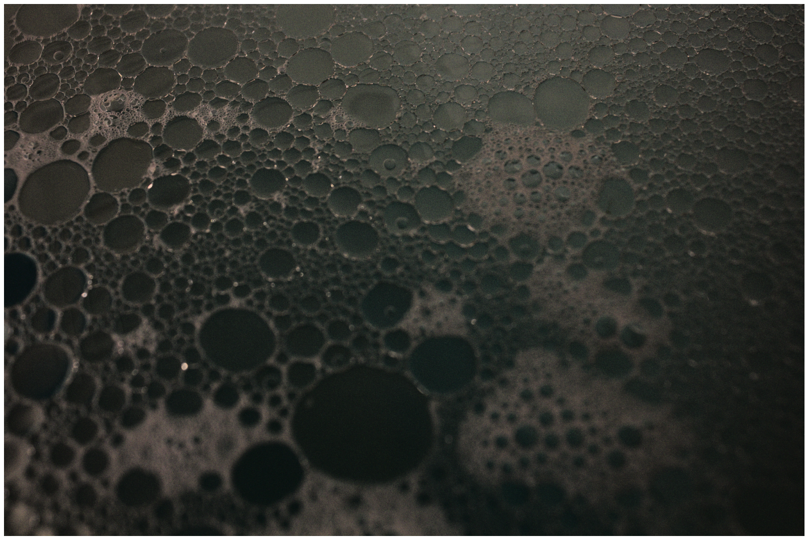


Figure 5: Final image

## V. Conclusion

While I am happy with this final image, there are things that I would improve should I redo this experiment. One main change that I would make would be to use a more powerful, single-point light source. This would allow me to capture the reflections of the light off the bubbles much more clearly. I would also not have to sacrifice brightness in order to enhance the clarity of the image. Another way that I could improve the lighting issue would be to decrease the shutter speed, especially because this image is of a still fluid.

## VI. References

Labman Physics. (n.d.). Surface tension. Retrieved September 26, 2022, from http://labman.phys.utk.edu/phys221core/modules/m7/surface_tension.html

Lumen Learning. (n.d.). *14.1 Fluids, Density, and Pressure | University Physics Volume 1*. Lumen Learning. Retrieved September 26, 2022, from https://courses.lumenlearning.com/suny-osuniversityphysics/chapter/14-1-fluids-density-and-pressure/

Mater Christi School. (2015, March 25). *Makerspace: Liquid Density Experiment in 1st Grade*. Mater Christi School. Retrieved September 26, 2022, from https://mcschool.org/2015/03/inventors-workshop-liquid-density-experiment-in-1st-grade/

MIT. (n.d.). *Soap bubbles, surfactants, detergents*. Retrieved September 26, 2022, from https://web.mit.edu/nnf/education/wettability/bubbles.html