Density Display

Get Wet Assignment #1

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MCEN 5151 Flow Visualization

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Introduction

The goal of this experiment was to showcase Rayleigh-Taylor Instability, which occurs when a lighter fluid pushes on a heavier fluid.[1] For this experiment, the lighter fluids are olive oil and water and the heavier fluid is dish soap. As the dish soap was poured on top of the oil and water, the weight of the soap caused it to fall through the oil and water, producing a Rayleigh-Taylor Instability. The interaction of these three fluids was captured in the presented image.

Flow Apparatus

The flow apparatus used in the experiment was very simple, consisting of only a glass. The dish soap was poured in first. Then, water was gently poured over the top of the dish soap, to avoid mixing. Next, olive oil was poured on top of the water. The glass was left for a few minutes to allow the fluids to settle into distinct layers. Then, dish soap was poured in on top of the olive oil. Photos were then taken as the dish soap traveled through the other fluid. A diagram of the experimental setup is shown below in Figure 1.

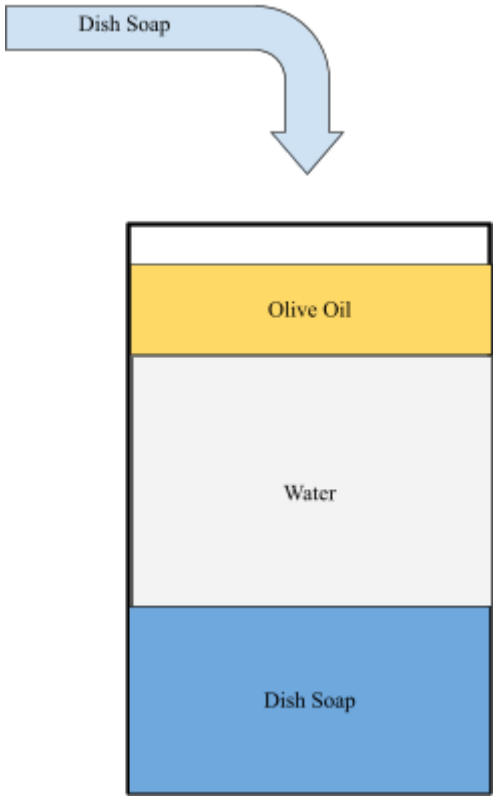


Figure 1: Diagram of experimental setup.

Fluid Dynamics

The focus of this experiment was the Rayleigh-Taylor instability, which occurs at the interface between fluids of differing densities. The three fluids, olive oil, water, and dish soap, all have differeing densities, as shown in Table 1.

Fluid	Density (kg/m^3)
Olive Oil[2]	895
Water	997
Dish Soap[3]	1120

Table 1: Density of fluids used

The fluids settled into the glass from highest to lowest density, resulting in three distinct layers. As the dish soap was poured on top of the olive oil, it began to form small perturbations in the interface between the olive oil and water. As the force of gravity continued to pull on the dish soap, it created instabilities and distortions in the interface, eventually breaking it and causing the dish soap to fall through the oil and water.

At the same time, the dish soap acts as an emulsifier on the oil, dispersing the oil droplets throughout the soap. Since soap can act as a polar molecule, it begins to orient itself with the hydrophobic end of the molecule around the oil molecules. Eventually, the soap stabilizes and essentially creates a barrier around the oil molecules. As soap molecules are heavier than the oil, they still sink through the water. This results in the green tendrils of soap visible within the water. The green color comes from the combination of the blue soap and yellow oil. An example of the emulsification process is shown in Figure 2.[4]

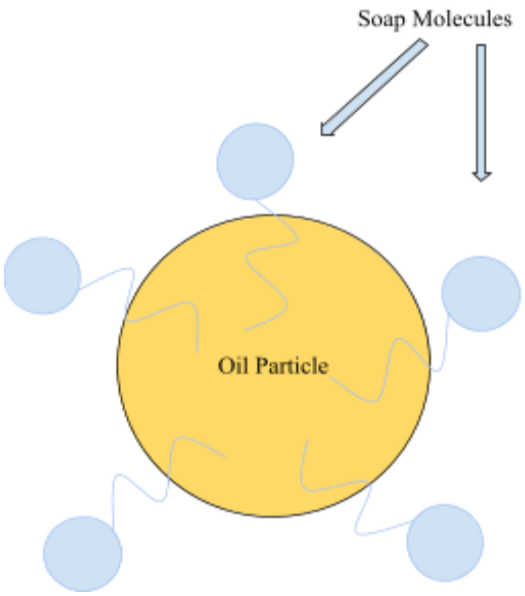


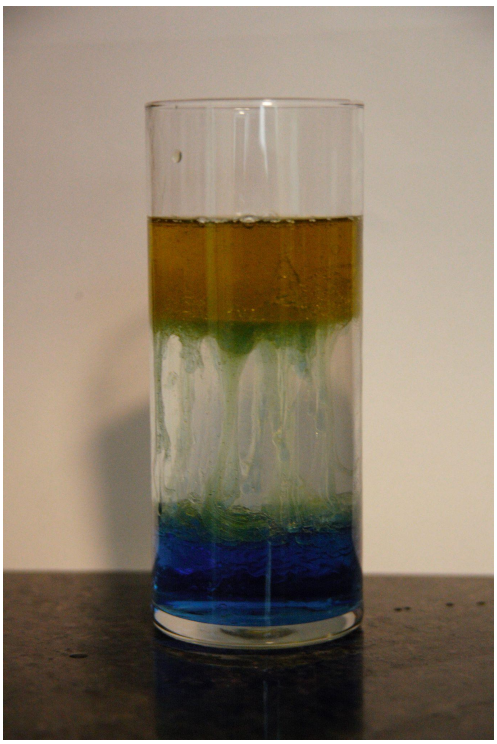
Figure 2: Example of soap acting as an emulsifier on oil

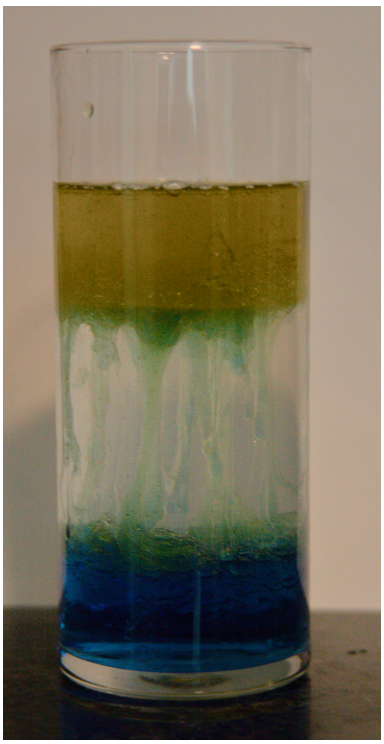
Visualization Technique

The visualization technique for this experiment was relatively simply. I used Kirland Signature olive oil, tap water, and Dawn dish soap for my fluids. I experimented with food coloring, but found that it made the image much harder to read. I used white printer paper as a backdrop, and used a combination of natural light and fluorescent lights in my kitchen to light the glass. I also place the camera on a tripod to help prevent movement while taking photos.

Photographic Technique

The image was captured using a Canon EOS 5D camera with a Canon EF 28-200mm lens. This lens has an aperture range of f/3.5-5.6 and a filter thread diameter of 72 mm. The distance from the object to the lens was about 1.5 feet with a field of of about 12°. The exposure was 1/125 sec., the ISO was 6400 and the aperture was max. I chose these settings to brighten up the image as much as possible. I was having a lot of trouble lighting my image. These settings unfortunately created some graininess and issues in my photos. The original and edited images are shown below in Figures 3 and 4.





Figures 3 and 4: Original and edited images.

I used darktable to process my image. I tried again to brighten up my image by changing the contrast. I also sharpened the image to show more detail on the finer parts of the image. I also cropped and rotated the image to reduce unnecessary background.

Conclusion

This image shows an example of how fluids with different densities interact. While this can be a common experiment used to introduce the concept of fluid density, many high-level concepts are on display. I like the variety of colors in the image. I dislike the lighting of the image, as well as the graininess of the image as a whole. I think in the future I will be using natural light to help brighten my image. I also think that I will be focusing on fluid interactions that are larger in scale, to help avoid any issues with zoom and focus. To develop this example further, I could use more fluids, to show the Rayleigh-Taylor instability across multiple interfaces.

References

[1] D.H. Sharp. An overview of rayleigh-taylor instability. Physica D: Nonlinear Phenomena, 12(1– 3):3–10, 1984.

[2] M S Sarjadi *et al* 2019 *J. Phys.: Conf. Ser.* 1358 012007

[3] D'cruz, J. (2023, July 25). *Density of dish soap: What you need to know*. Denseme. https://denseme.com/density-of-dish-soap/

[4] Friedman, I. (2023, March 26). *How does soap work?*. Chagrin Valley Soap & Salve. https://www.chagrinvalleysoapandsalve.com/blogs/idas-soap-box-blog/how-does-soap-work