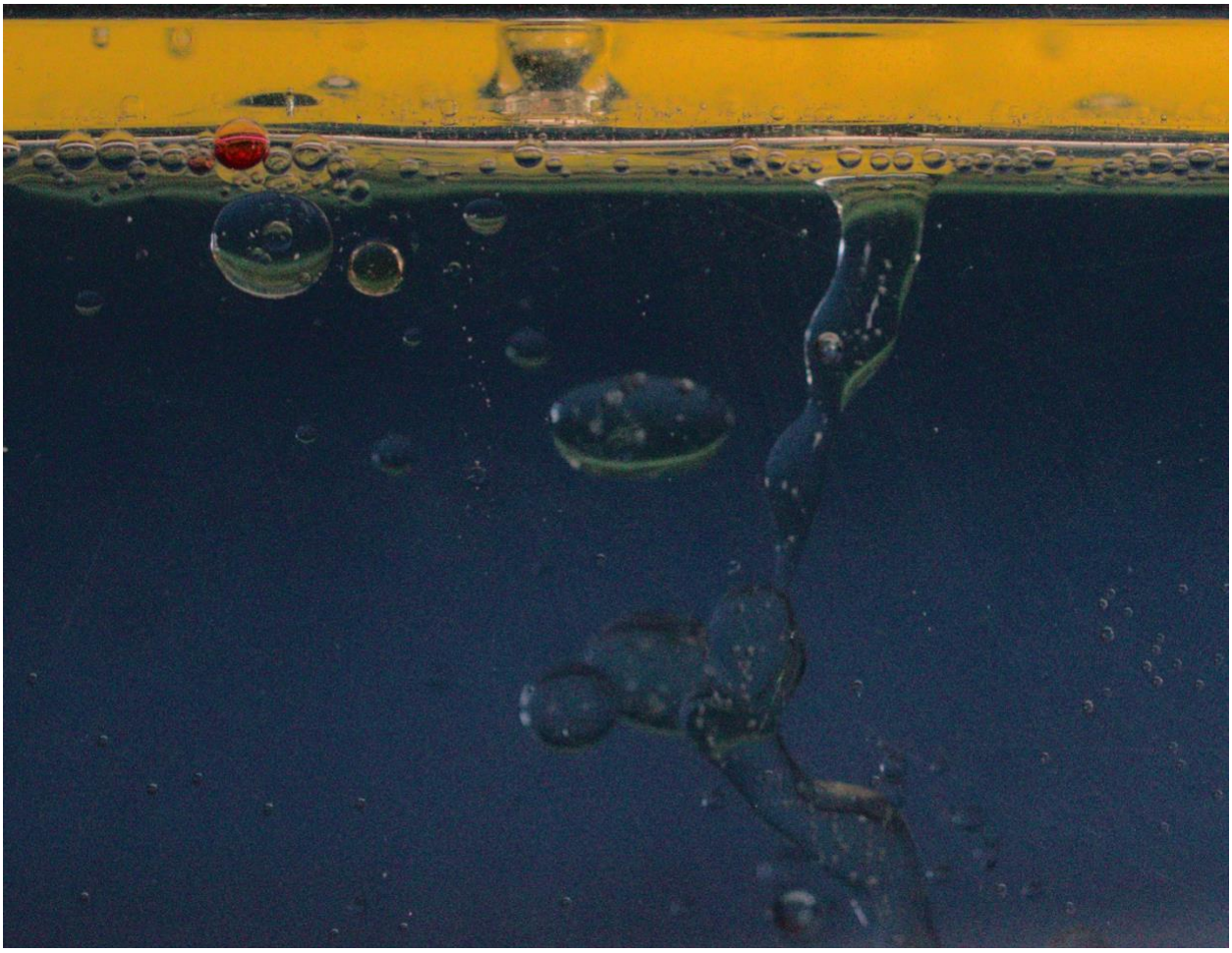
Team Third: The Dance of Separation

Izzy Young
Assistance from: Avery Fails, Sarah Hartin, and Monica Luebke

MCEN 4151: Flow Visualization
12/06/2023



1 BACKGROUND

This image is capturing oil and water not mixing. The original intention was to capture shear forces and a boundary layer from a flat plate over a surface of oil and water. Unfortunately, my team and I were unsuccessful at capturing this boundary layer. Instead, we were able to snap photos of the hydrophobic properties of oil in water. The intention with this was to capture interesting flow of oil and its hydrophobic qualities in water. The goal was to capture interesting bubbles of oil within a darker bubble. This experiment was done in collaboration with Avery Fails, Sarah Hartin, and Monica Luebke. Many different flows were captured with the two fluids, this report will describe the boundary created and the fluid physics behind the image.

2 EXPERIMENTAL SETUP

This experiment was set up at the ITLL at the University of Colorado Boulder. The image was setup on a table in the ITLL in a dark room with no windows. A white backdrop was setup and then a fifteen-gallon fish tank was placed on the white background. The fish tank was then filled with water about six gallons of water and blue food dye was added. Next, canola oil was added to the water. About a two-inch layer of canola oil settled on top of the water. Then a gush of oil was poured into the tank and that was when this image was captured. Figure 1 represents the items used to create the setup.

Figure 1: Canola Oil, blue food coloring, and water were used to create the fluid mixture for the image.

The mixture was poured into a fish tank shown in figure 2.

Figure 2: Fifteen-gallon fish tank that held the fluid.

The light was set up to the right of the tank. The entire setup can be seen in figure 3.

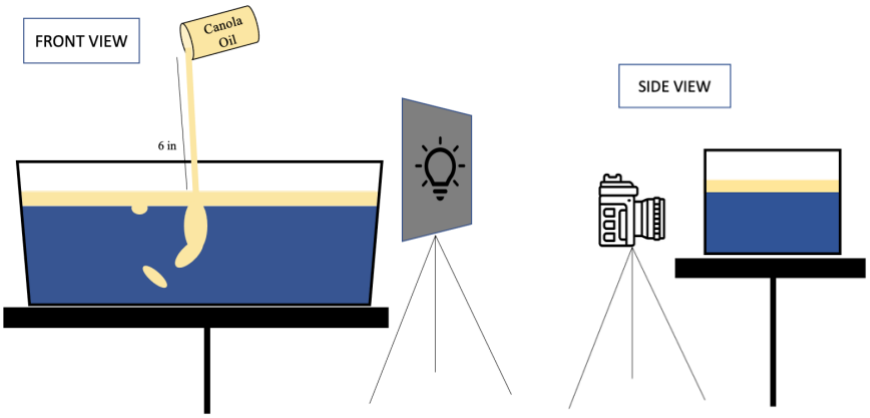


Figure 3: Diagram of setup. The front view is the angle that the camera saw. The side view is with the camera.

A picture of the setup can be seen in figure 4.

Figure 4: A photo of the final setup before dye and oil were added.

The final part of the image that must be explained in the setup is the red bubble at the very front on the left. This was the result of mixing colors and trapping some pink food dye mixed with water trapped in the oil layer.

3 PHYSICS OF THE FLOW

This photo shows the hydrophobic properties of oil in water. Water and oil do not mix because H_2O is a polar molecule with a positive and negative end [2]. Due to this polarization, the molecules of water stick to each other: the positive of one end sticks to the negative of another. Oil is the opposite; it is a nonpolar molecule with no charge. This leads the oil molecules to stick to each other. As the water sticks to itself, the oil sticks to itself, meaning the two fluids do not mix.

The water sinks to the bottom of the fish tank because the water is much denser than oil. The droplets of oil migrate upwards through the water because of this difference in density. Oil and water are immiscible liquids [3]. As the oil is poured into the water, the equilibrium of settled oil on top of water is disturbed and oil droplets in water are formed simultaneously as water droplets are formed in the oil (for example the red bubble). As the oil is poured into the water a jet of descending oil moves the incompressible water out of the way. Then, buoyancy takes over as some of the oil pinches off into bubbles that then float to the top.

There is also a layer of surface tension separating the water and oil. To create the system, energy needs to be added to generate the increased surface area from the droplets. The oil being poured into the dyed water creates this surface tension directly in the pool of water and creates beautiful globules of oil in water.

4 VISUALIZATION AND PHOTOGRAPHY TECHNIQUES

This photo was taken using marked boundary techniques [1]. The difference between the viscosities of oil and water makes a clear difference between the bubbles and the background.

There was quite a bit of post processing done to this image to better highlight the flow without deterring from any of the fluid physics. I edited the white and black point as well as adjusting the highlights and shadows of the image. The main color alteration I adjusted was the red and some of the blue. See figure 5 for the final colors captured from Darktable.

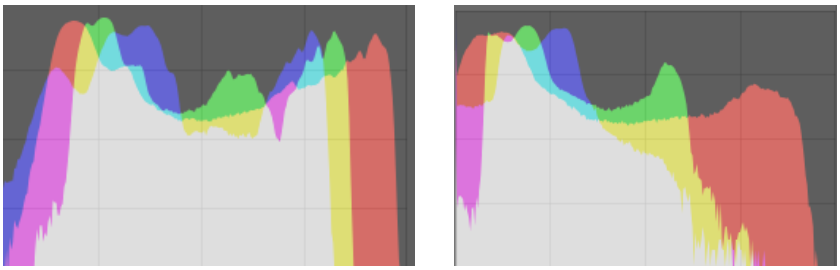


Figure 5: The color arrays of my image both before (left) and after (right) being post processed in Darktable.

In addition to altering the colors, I also increased the contrast to define the oil bubbles from the darker blue background. I also cropped the image as to only capture the main bubbles of oil. Figure 6 shows the edited and unedited images.

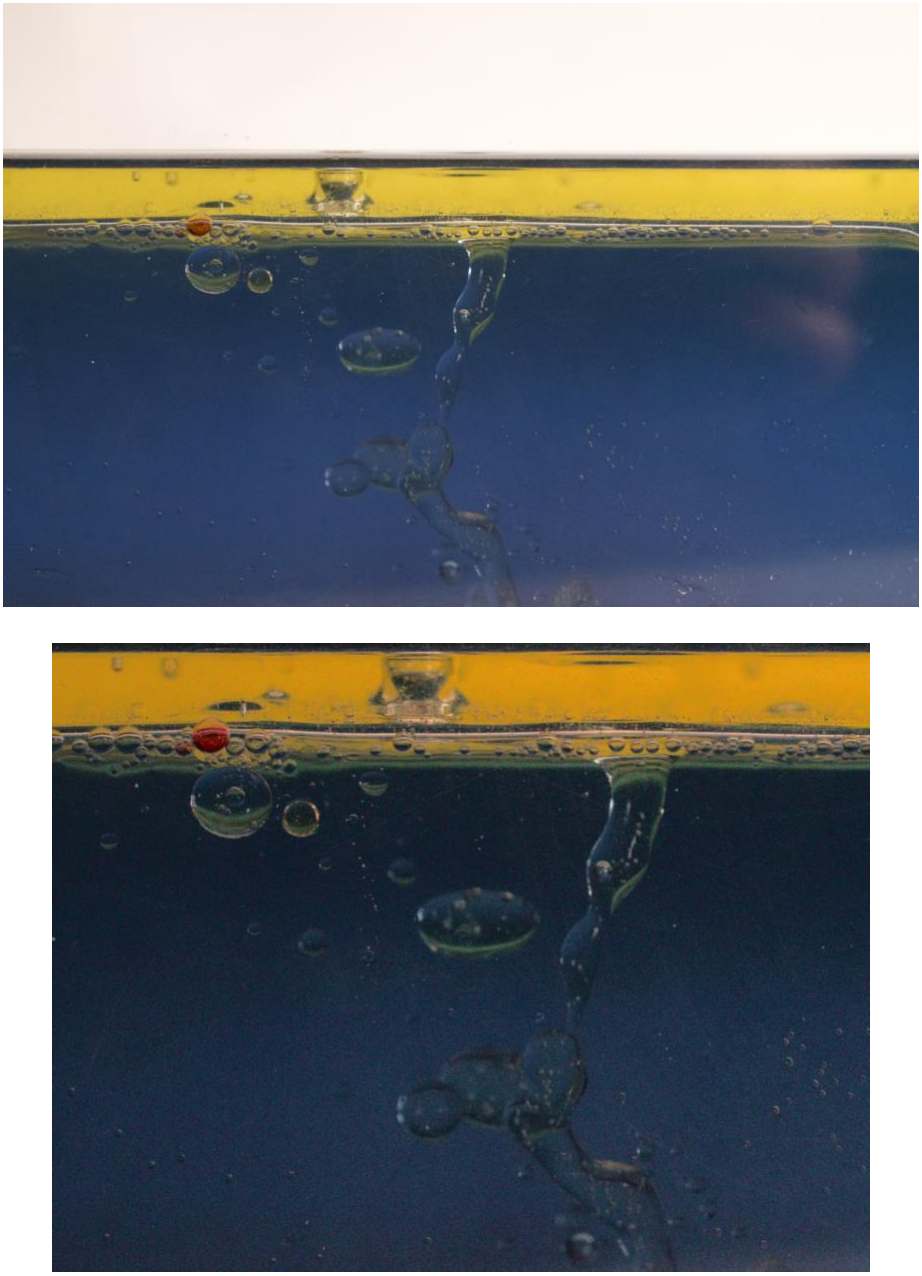


Figure 6: The image on the top is the unedited and uncropped picture and the bottom is the edited photograph.

The unedited image is 6,000 x 4,00 pixels. The edited image is 3,593 x 2,770 pixels. The spatial resolution of this image on the order of two because the ratio is about $1{:}10^3$, therefore is three

decades. When this image was captured, the oil was poured, created a motion blur. Due to the blur, this image is not time resolved, it instead has time averaging creating some of the blur [1].

The camera used was a digital Nikon D5500 camera on a Nikkor 18-55mm lens with a focal length of 40mm. The ISO was set to 6400 and the f stop at f/7.1 and the shutter speed of 1/800s. The focus was manual focus.

The camera was less than a foot away from the surface of the liquid and the field of view was 6 inches.

The lighting was a stand light provided by Professor Jean Hertzberg. The rest of the room was completely dark: all the lights were turned off and there was no natural light from windows. We used a combination of white and yellow light. The settings can be seen in figure 7.

Figure 7: Lighting settings of the stand light used to create indirect lighting in the photo.

5 CONCLUSION

Using marked boundary techniques, this image is able to reveal some beautiful globules. The hydrophobic properties of oil are demonstrated in this image. I am proud of how this image turned out, especially due to the post processing that enhances the image. I like how the image looks and captures interesting bubbles. The one thing I dislike is that I wish it was in better focus with a sharper line separating the bubble from the water, making a clearer marked boundary. I think the fluid physics are shown very well. I am curious if the oil could be dyed a color to make

it not just yellow and create more interesting contrast in colors. I would improve by repeating the experiment even more times to capture even more variations of this flow and practicing getting a better focus on the movement. All in all, this image fulfilled my intent well by using oil to highlight physics in a cool way.

6 ACKNOWLEDGEMENTS

This photo was captured with assistance from Avery Fails, Sarah Hartin, and Monica Luebke.

7 REFERENCES

[1] Hertzberg, Jean. “Flow Vis Guidebook.” *Flow Visualization*, 13 July 2023, www.flowvis.org/Flow%20Vis%20Guide/overview-3-lighting/.

[2] Vanstone, Emma. “Why don’t oil and water mix.” *Science Experiments for Kids*, 03 November 2021, https://www.science-sparks.com/why-dont-oil-and-water-mix/#:~:text=The%20structure%20of%20an%20oil,so%20the%20two%20never%20mix. Accessed 24 Nov. 2023.

[3] Cormack, D. (1999). The Oil-Water System. In: Response to Marine Oil Pollution — Review and Assessment. Environmental Pollution, vol 2. Springer, Dordrecht. https://doi.org/10.1007/978-94-015-9301-4_2. Accessed 24 Nov. 2023.