Team Second Report

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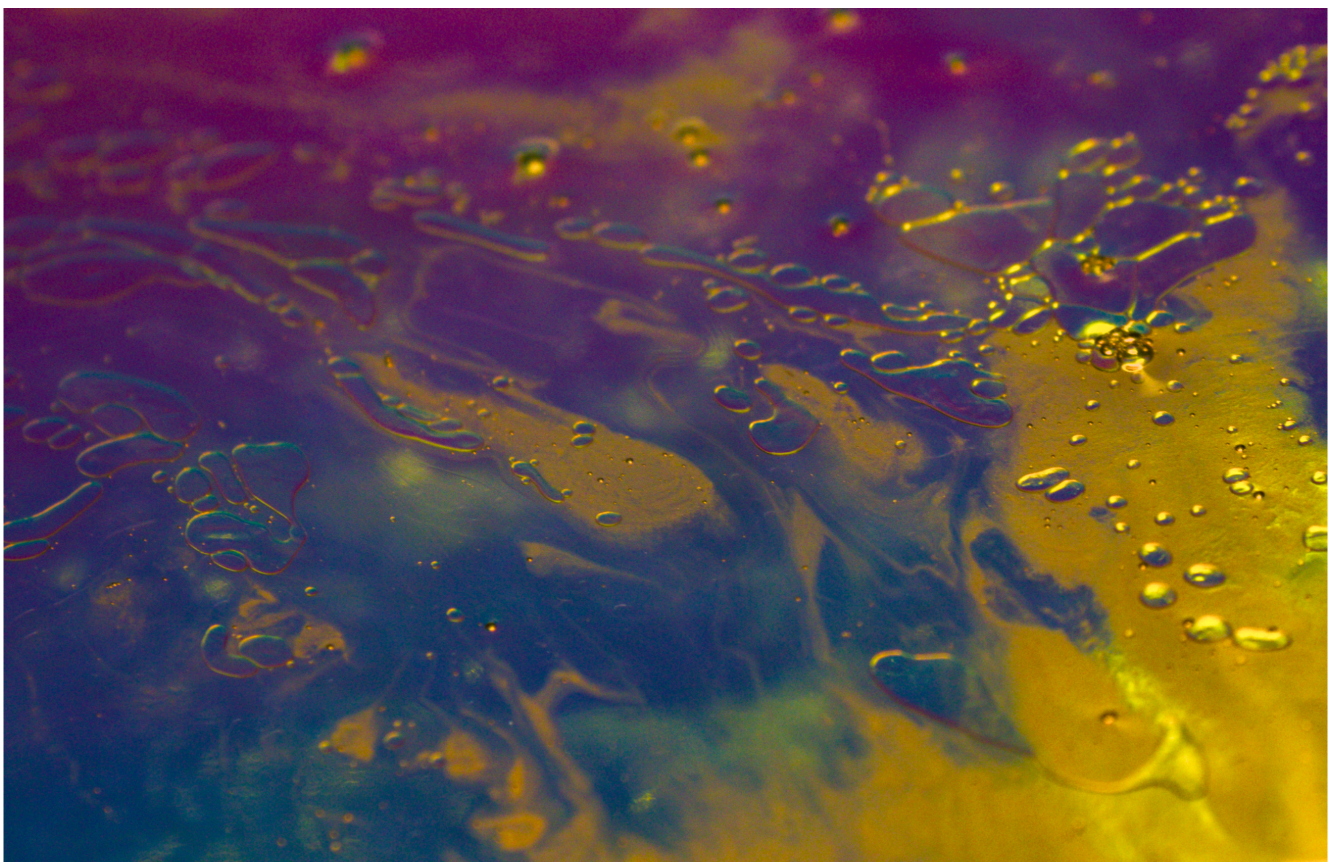

Figure 1. Final Image of the Interaction Between Oil, Dish Soap, And Water on a Glass Pane above a Reflective Background

Background

This image was created for the fourth assignment of the Flow Visualization course, Team Second, with the assistance of Jessica Vo and Adiba Ashrafee. It captures the resulting flow patterns from layering oil, dish soap, and water on a glass pane. The image highlights the intriguing bubble formations and their movement during the experiment. The goal was to illustrate the varying properties of the liquids and their interactions, as well as the way the paper beneath the glass pane appeared through the liquids.However, the liquids did not distort the patterned papers as expected. Therefore, we opted to use only a multi-colored reflective paper underneath, adding an extra layer of dimension to the visualized flow.Adiba, Jessica, and I collaboratively set up the experiment and took turns pouring the different liquids throughout the experiment. Each of us contributed materials, some of which were borrowed from the Integrated Teaching and Learning Laboratory (ITLL) at the University of Colorado Boulder. During the photography phase, Jessica assisted by holding a ruler for focus and size reference.

Fluid Physics

The fluid dynamics seen in this image show flow phenomena of round, three-dimensional bubbles and elongated, flatter bubbles within the fluid. These differences can be explained by the interplay of surface tension, buoyancy, and viscous forces.

Round bubbles form as surface tension minimizes their surface area, resulting in a spherical shape, as described by the Young-Laplace equation:

$$\Delta P = \frac{2\sigma}{R}$$

Here, ΔP is the pressure difference between the inside and outside of the bubble, σ is the surface tension of the liquid, and R is the bubble's radius. The rounder bubbles are observed in regions containing dish soap, which has a lower surface tension compared to oil or water. These bubbles remain stable in areas of low shear, where buoyancy primarily governs their behavior.

In contrast, elongated, flatter bubbles form in regions with higher shear forces or at interfaces, such as between oil and water in the experiment. The deformation of these bubbles can be quantified by the Capillary Number (Ca):

$$Ca = \frac{\mu U}{\sigma}$$

In this equation, μ is the dynamic viscosity of the fluid, U is the velocity of the bubble relative to the fluid, and σ is the surface tension. A higher Capillary Number indicates that viscous forces dominate, leading to greater bubble elongation.

Additionally, bubble shapes are influenced by their interaction with solid or liquid surfaces, which is governed by the contact angle (θ):

$$cos\theta = \frac{\sigma_{sl} - \sigma_{sg}}{\sigma_{lg}}$$

Here, σ_{sl} is the solid-liquid interfacial tension, σ_{sg} is the solid-gas interfacial tension, and $\sigma_{lg}$is the liquid-gas interfacial tension. The contact angle determines how a bubble spreads along the interface.

These principles explain the transition of bubble shapes from spherical to elongated and flatter forms, depending on the flow conditions and interfacial interactions within the surrounding fluid.

Visualization Technique

The visualization techniques used to capture the final image (Figure 1) are straightforward and easy to replicate. To achieve this effect, we used dish soap, minimally colored oil, tap water, a glass pane, a lamp, and holographic vinyl placed underneath to add color. The glass pane was propped above the vinyl using scrap wood, which resulted in some shadows from the liquids appearing on the paper in certain images. We poured the liquids onto the glass pane, alternating between oil, water, and dish soap in different locations. Without external interference, the fluids began spreading across the pane due to differences in their viscosities and surface tensions, forming the air bubbles seen in the final image. The lamp, an LED ring light, was positioned perpendicularly above the surface. Additionally, overhead lighting from performing the experiment indoors in the evening contributed to the illumination. Some light was likely reflected off the holographic vinyl beneath the glass, enhancing the visual effect.

Photographic Technique

The image was taken on a Canon EOS 2000D (also known as the Canon EOS Rebel T7) from a short distance above the flow. The lens used was a Canon zoom lens with an 18-55mm focal length, 1:3.5-5.6 aperture, and a thread diameter of 58mm. The original picture (*Figure 2*) was 6000 x 4000 pixels and was cropped to 4042×2606 pixels (*Figure 1*) which focused on the movement of the bubbles and their different shapes.

Figure 2. Original Image of the Liquids on the Glass Pane

The photo was taken with 640 ISO, a focal length of 55 mm, an aperture of *ƒ*9, and a 1/160s shutter speed. Using darktable the image was post-processed to increase the contrast and vibrance, highlighting the texture and creating more dimension within the image. The contrast was increased to emphasize the edges of the bubbles and their texture. I also messed with the saturation, hue, and color brightness to further enhance the colors.

Conclusion

The image highlights the beauty of surface tension and bubbles, showcasing their effects against a vibrant, colorful background. The opacity of the dish soap, in contrast to the oil and water, adds an appealing element that enhances the depiction of the flow. I am particularly pleased with how vivid the colors turned out and how the asymmetrical flow of the fluids still aligns with the color gradient. While I am satisfied with the outcome, I wish I had been able to capture a more detailed, close-up image of the bubbles and their shapes, but I did not have access to a macro lens. In the future, I would like to experiment with different backgrounds to observe how they influence the way colors interact with the bubbles. Additionally, I would place the glass directly on the background to minimize shadows. Overall, I believe the image successfully captured my intended visual and fluid flow effects.

References

Digital Photography School. (n.d.). *How to create abstract photos with oil, water, and dish soap*. https://digital-photography-school.com/create-abstract-photos-oil-water-dish-soap/

Springer. (n.d.). *Flow visualization*. In M. D. Greenberg (Ed.), *Encyclopedia of fluid mechanics* (pp. 1507-1513). Springer. https://link.springer.com/referenceworkentry/10.1007/978-0-387-48998-8_1507