Mixing of Water and Oil

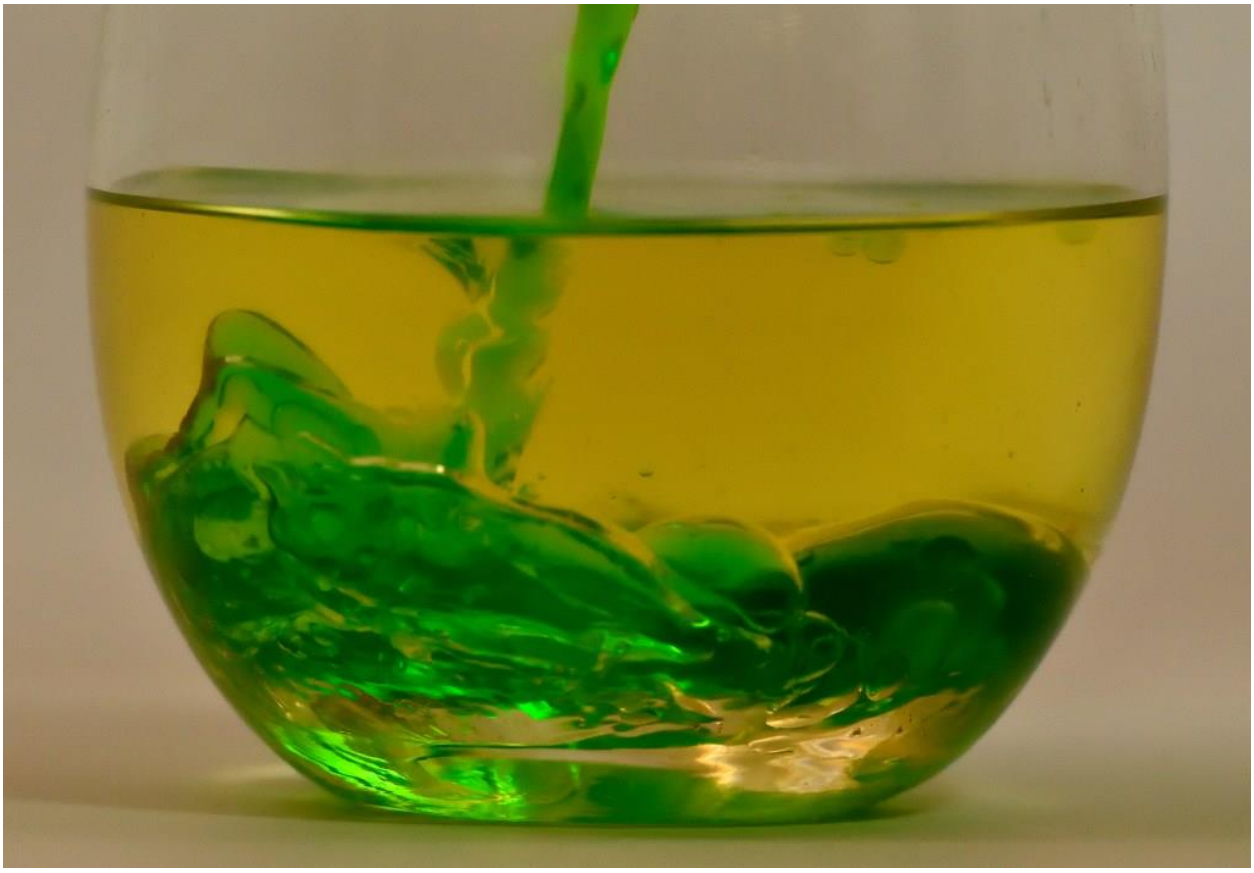

Figure 1: Final Photograph

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Get Wet Assignment

Flow Visualization – MCEN 5151

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Introduction

The image seen on the title page was the final product used for the “Get Wet” assignment. The point of this assignment was to get a hands on, first look at the world of flow visualization. For the subject content of my image, I chose to focus on the interaction of water and oil. The intent of the image was to see the separation of the different fluids and how they flow together without mixing. This is a basic phenomenon that allowed me to focus on and perfect some techniques necessary to successfully image the flow. This report will focus on an explanation of the flow and how the procedure involved in taking the photo.

Experimental Setup

The basic setup for imaging this flow is relatively simple. You only need a few materials and the setup should take no more than a few minutes to complete. The diagram in Figure 2 shows the positioning of everything in the setup.

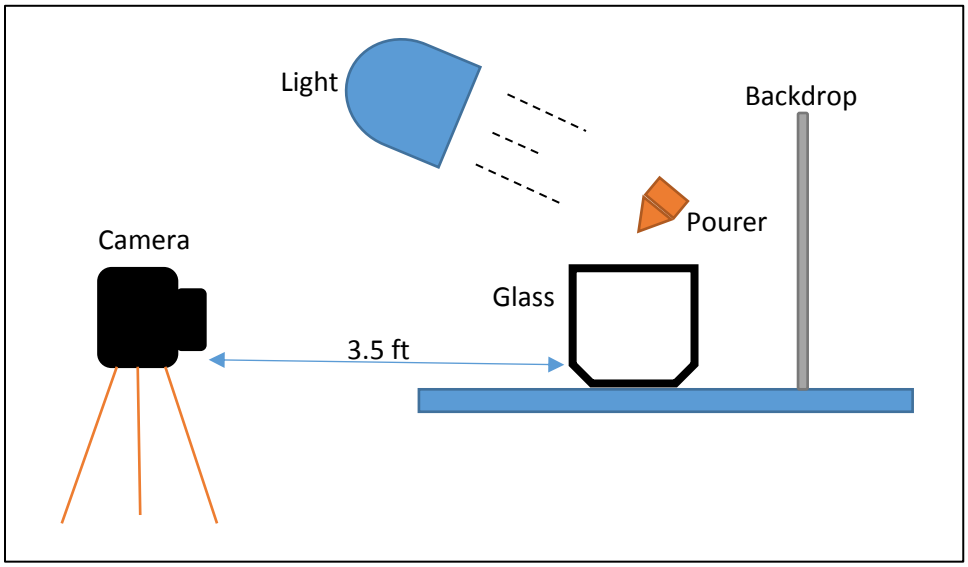

Figure 2: Setup of Water and Oil Experiment

Start by filling a 3in diameter glass with approximately 4oz of canola oil, the exact amount isn’t critical. Dye some water with any standard food coloring until the color is dark enough to create a good contrast between the oil. A standard light was reflected off the white backdrop, which wrapped 180 degrees around the glass to provide a bright atmosphere without direct light on the glass. The camera was positioned 3.5 feet away from the glass, allowing for adequate depth of field to image the fluid flow clearly. Finally, the water needed to be poured into the canola oil. The flow was slow and constant to allow for “mixing” to occur in the glass. Several pictures were taken as the water and oil mixing occurred. The experiment is simplified if one person pours the water, while another person is taking the picture.

Explanation of Fluid Flow

The interaction of the fluid flows in this experiment is deeply rooted around the two liquids—oil and water—never mixing. The miscibility (ability to mix) of liquids is related to molecular structure of the individual liquids. Once the liquids are mixed, the intermolecular forces of attraction between the liquids are what drive the their "need" to form a homogeneous mixture [1]. If those attractive forces are not equal between the two liquids, then they will form a nonhomogeneous mixture. The molecules of the liquid with the stronger intermolecular force will bond with each other, leaving the other liquid to form a separate layer. A simple rule used by chemists to summarize this phenomenon is "like dissolves like", meaning liquids with similar polarity are miscible with each other. Looking at our interaction, water is polar and oil is non-polar. Therefore, water and oil shouldn't mix with each other, and they don't.

Since the two liquids in this experiment are immiscible, there are some unique interactions that take place. The initial event that happens when the water is poured into the oil is it cuts through the oil and settles at the bottom of the glass, below the oil. This can be explained by the buoyancy forces at play. The buoyant forces created by the oil can be described by the following equation [2]:

$$F_b = \rho_{oil} V_{H2O} g = .0090N$$

This buoyant force needs to then be compared to the weight of the water in the oil. If the buoyant force is larger, then the water should rise to the top. The volume of the water isn't known since it was a constant stream throughout the process. Using a standard volume of 1 cm^3, we can calculate the buoyant force and compare.

$$W_{H20} = \rho_{H20} V_{H2O} g = .0098N$$

From the calculations above, you can see that the weight is larger than the buoyant force. That is why the water settled directly to the bottom of the glass.

Visualization Techniques

For this experiment, dye was used to create better contrast with the oil so the fluid flow could be seen easier. Five drops of BRAND NAME gel drops were added to 8oz of water and mixed in a blender. The blender was necessary for the gel style drops since they don't mix too well by hand. For lighting, a desk lamp was used to illuminate the backdrop of the setup. By illuminating the large white backdrop, the glass was able to be well lit while not having any problems with reflections. No camera flash was used for the picture.

Photographic Techniques

There are several choices that I had to make to enable the picture to turn out as expected in the end. To begin, field of view is one of the most noticeable features of the photo. I kept a relatively large field of view in order to allow as many bubbles and mixing to stay in focus. However with most of the mixing being uniform throughout the depth of the glass, is wasn't as noticeable as I initially thought.

The picture was shot with a Nikon D5500 camera. The setting used were: ISO 4000, shutter speed – 1/1000 sec, and aperture- f/8. That high of a shutter speed was used to reduce the motion blur that would occur with the shutter open for any longer. A 55mm – 200mm lens was used in order to get a more zoomed in look at the fluid interaction. However, in order to focus correctly the camera had to be placed farther away. So the gains may have been lost in that regard. The original and edited photo have the size (in pixels) of 6000x4000, just some post processing was done.

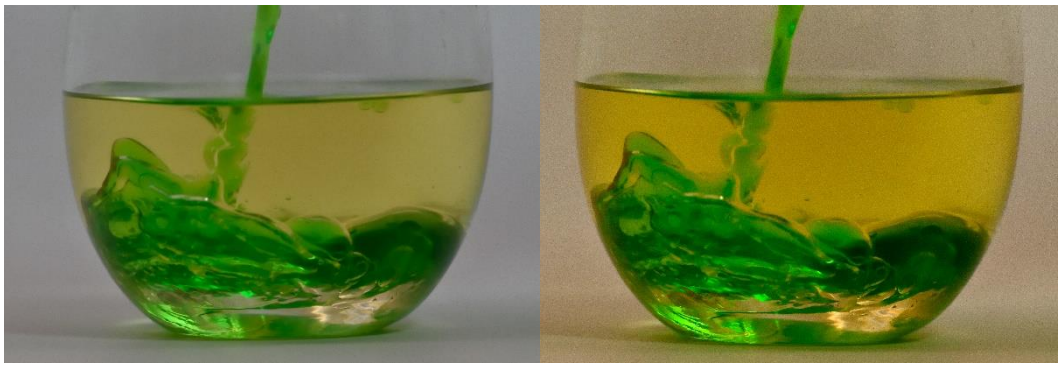

Figure 3: Original photo on the left and final photo on the right.

Nikon's RAW file editor was used to adjust some basic elements to make the image look better overall. The original image compared to the final image can be seen in Figure 3 above. To start, the white balance was adjusted to a more warm color than the pale original color. The sharpness was also adjusted to get the water bubbles at the bottom as crisp as possible. Finally the color was slightly changed by adjusting the contrast and using a color booster tool.

Conclusion

This first assignment was an excellent first look into the world of flow visualization. It was found that the process of flow visualization is much more difficult and time consuming than one would initially think. In the end, the image turned out great and it fulfilled the original intent of the photo. If I were to improve on this image, having a different angle of view and having more depth would have made the picture that more interesting.

References

[1] Sametz, Geoffrey. University of Deleware, Chemistry 102. From http://www1.udel.edu/chem/sametz/102Fall11/dc1-8.pdf

[2] Munson, Bruce R, Donald F. Young, and T H. Okiishi. Fundamentals of Fluid Mechanics. Hoboken, NJ: J. Wiley & Sons, 2006. Print.