Get Wet

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This report outlines the process used to capture vortex rings formed by mineral oil flow in mineral oil with still photography under ultra-violate light. Mineral oil containing UV dye was injected into a still bath of mineral oil to create ring vortices. A low ISO, low F-stop, and long shutter speed were used to capture the image using digital photography. The image was processed to bring out colors and remove blemishes to create the final image.

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I. Introduction

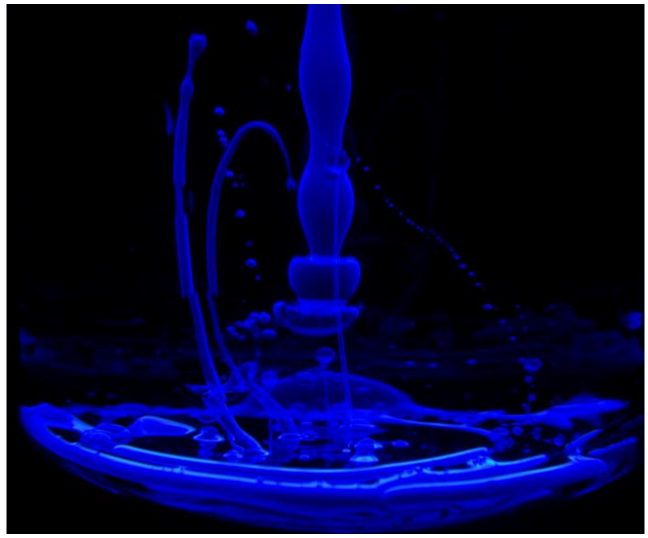

Figure 1: Initial Experimentation

The purpose of this assignment was to develop an initial understanding of flow visualization techniques. This report discusses the physics behind the flow phenomena observed, experimental setup, and photographic techniques for the "Get Wet" assignment. Initially the experiment was an attempt to capture the interaction of a more dense fluid falling through a less dense fluid. Here laundry detergent was dropped through water under a blacklight resulting in images like that in Figure 1. This experiment produced some very satisfactory results, but also triggered further experimentation with similar density fluids. It was quickly realized that the injection of a fluid into itself could almost freeze the fluid in motion allowing it to be easily photographed in low light conditions. For the final experiment mineral oil was dyed with a UV dye and injected into clear mineral oil creating ring vortices. These vortices were highly visible under the blacklight and were held still by the equal viscosity of both fluids. Cameron Trussell assisted with the experiment.

II. Experimental Setup

The final experiment was setup in a dark bathroom against a black poster board backdrop. An 18 inch fluorescent blacklight was positioned over the experiment and was the only light source. A clear drinking glass was filled with mineral oil and positioned under the black light. A second glass was then filled with "Tide Vivid White + Bright" laundry detergent and dropped into the center of the glass. Due to the relative density of the laundry detergent to the mineral oil the detergent remained within the smaller glass and served as a base for the experiment. A small amount of mineral oil was then mixed with "NAPA's UV Dye" in a small dish and drawn up into a 10 cc syringe. The syringe was carefully lowered into the large glass until the tip was about ½ inch above the laundry detergent. Approximately 1 cc of UV oil was ejected from the syringe at a rate of about 1 cc/s. The syringe was then raised an arbitrary amount and another 1 cc of oil was deposited into the glass. This process was repeated 5-6 times, each time creating a new vortex ring. The experimental setup is summarized by the schematic in Figure 1.

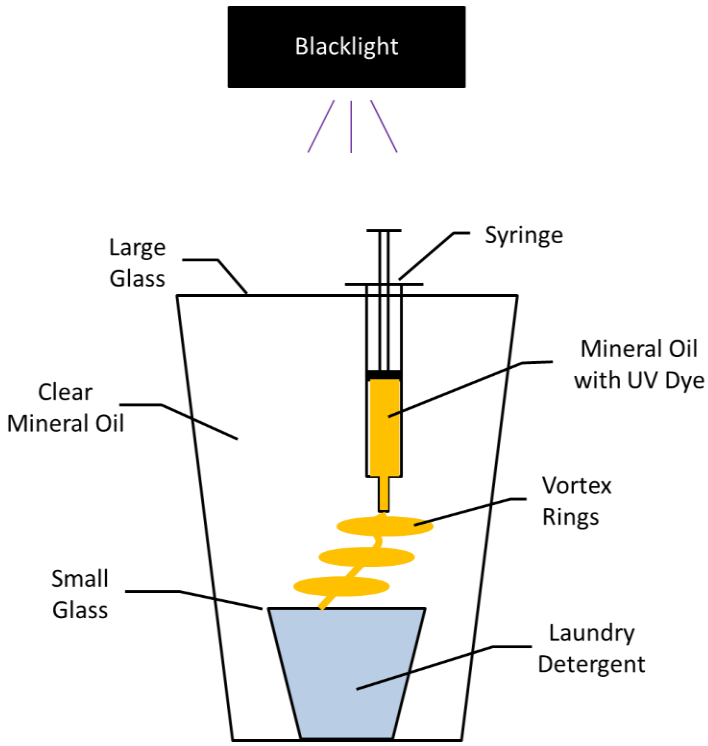

Figure 2: Experimental Setup

III. Description of flow Physics

The primary flow captured in the image was the vortex ring phenomena which resulted from the jet injection of fluid by a syringe. As the fluid was forced from the syringe at a velocity of approximately 0.3 m/s it encountered a friction force from the stationary fluid already in the glass. This caused the streamlines on the outer edge of the jet to slow while the streamlines in the center maintained their velocity. These interactions caused the slower fluid to rotate creating a vortex phenomenon.

A. Reynolds Number

The viscosity of mineral oil was found, according to the *Food and Agriculture Organization of the United Nations*, to be roughly 10 mm^2/s [1]. Effects from the UV dye are being ignored since such a small amount of dye was added. Since the fluid was ejected from the syringe at approximately 1 cc/s and the syringe opening had a known diameter of 2 mm it was estimated that the fluid was exiting the syringe at 0.3 m/s using basic thermodynamics [2]. From this information the Reynolds number was calculated using Equation 1 to be 64.

$$Re = \frac{VL}{\nu} = 64$$

Equation 1: Reynolds Number

This is a very low Reynolds number. However, considering the high viscosity of the fluids involved and the small fluid sizes being used it is very reasonable.

IV. Photographic Technique

B. Image Capture

A Cannon PowerShot G9 digital camera with a macro lens adapter was used to capture the image. Various shutter speeds, exposures, and ISO settings were experimented with in order to capture the image. Creating photographs in the low light, blacklight, conditions proved difficult. Originally photographs were taken using high ISO settings and high F-stop values in order to maximize depth of field. However these photographs were grainy so the ISO was lowered to 100. The final image was captured using a shutter speed of 1/20 sec, F-stop of f/2.8, ISO of 100, and focal length of 7.4-44.4 mm. At these slow shutter speeds a clear image was difficult to capture without a tripod. Fortunately the stationary fluid made this process less difficult. The macro lens allowed the images to be captured with the lens a mere 2 inches from the glass containing the fluids.

C. Post Processing

After capturing the image it was adjusted using Adobe Photoshop. The most significant alteration was the adjustment of contrast. Overall contrast was adjusted using a manual S-curve to better highlight the lights and darks in the image. Then an S-curve was added to the red contrast to bring out the red coloring in the UV dye. A slight adjustment to the green contrast was made to decrease the amount of green visible in the image. After contrast adjustments were completed the image was cropped to remove extraneous background. After close inspection some small blue spots were found on the image from imperfections in the glass. The “Spot Healing Tool” was used to carefully remove these spots on the image. Extreme care was used to avoid adjusting the appearance of the fluid and only remove the blemishes. There were also a couple bad pixels that were also removed in the image. Figure 3 and Figure 4 show the image before and after editing in Photoshop respectively.


Figure 3: Before Editing **Figure 4: After Editing**

The original image was 3000x4000 pixels in dimension. After editing the final image size was 2960x3624 pixels. As can be seen, very little image was cropped.

V. Conclusion

In conclusion this image clearly demonstrates the vortex ring phenomena and the intent was fulfilled. The various styles of vortex rings are clearly visible in the image, especially after alteration of the image. Personally I think the image is too cluttered and if I were to repeat the experiment I would reduce the number of vortices present. Also, the image could be improved with a tripod and slower shutter speed with higher F-stop.

VI. References

VII.

[1] "Combined compendium of Food Additive Specifications: Mineral Oil," 2002. [Online]. Available: http://www.fao.org/ag/agn/jecfa-additives/specs/Monograph1/Additive-283.pdf. [Accessed 11 February 2013].

[2] M. J. Moran, H. N. Shapiro, B. R. Munson and D. P. DeWitt, Introduction to Thermal Systems Engineering, John Wiley & Sons, Inc., 2003.

VIII. Acknowledgements

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