Get Wet

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MCEN 4151: Flow Visualization
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Introduction:

The purpose of this assignment was to gain a general understanding of fluid photography and its many challenges. The subject matter was unrestricted and the main goal was to get your feet wet and have fun with fluid photography. For this assignment a Rayleigh - Taylor instability was used as the flow phenomena, and achieved using neon yellow highlighter dropped in water under a blacklight. The following report outlines the experimental setup, physics behind the flow phenomenon, and the photographic techniques used to achieve the image.

Experimental Setup:

In order to effectively capture the fluid in this experiment all ambient light was eliminated so that the backlight was the only source of light. The light used was the Chauvet DJ LED Shadow Blacklight Panel. The light was placed directly above the container, parallel to the waters surface. To soften and diffuse the light the LED array was covered in crumpled wax paper. After several attempts a large square Jar was chosen as the container in order to eliminate the distortion created by a rounded container. The container used was a glass jar about 30 fluid oz. Black fabric was used to surround the jar to create a neutral backdrop. The camera was placed at 90 degrees to the glass about 1 inch away. A diagram of this set up can be seen bellow in Figure 1.

To extract the fluorescent dye from the highlighter marker simply remove the end cap and take out the tube contained inside. Squeeze the tube above the container of water, about 2-3 inches above the surface, and drop a single drop of dye into the container. For this experiment a yellow Sharpie brand highlighter was used which contains fluorescein as the active fluorescent ingredient [1]. This is a nontoxic substance and is safe for humans. The photo was taken about 30 seconds after the drop impacted the water.

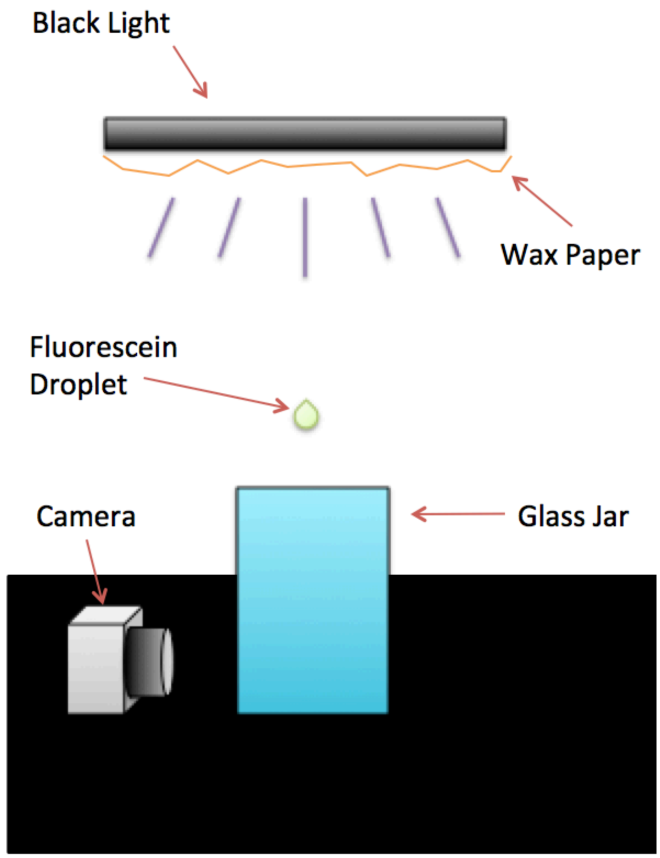

Figure 1 Experimental Setup

Flow Phenomenon:

The photograph captured an example of Rayleigh-Taylor Instability. This phenomenon occurs when a drop of one fluid settles in a fluid of lower density. The driving force in this case is gravity as it draws the higher density fluid to the bottom of the container. The fluid wants to be in the lowest energy state. As the dye falls it picks up speed increasing the Reynolds number until it becomes unstable and the plumes form [3]. Based on estimations for speed, diameter of flow, and kinetic viscosity of the dye the Reynolds number can be estimated. As the drop of dye falls the Reynolds number estimation is:

$$Re = \frac{UD}{v} = \frac{\left(0.038\frac{m}{s}\right)(0.02\ m)}{5.0x10^{-4}\frac{m^2}{s}} = 1.52$$

The velocity term (U) above is an estimation based on how fast the dye was falling through the water. The length term (D) is a rough guess at the diameter of stream of flow. The kinematic viscosity above was taken from an online data sheet for generic yellow highlighter ink [2]. This Reynolds number suggests stable laminar flow. This makes sense for the top part of the image but is not consistent with the turbulent plumes seen at the bottom of the image. Sources of error are abundant as many of the values are estimations.

Photographic Technique:

The camera used to achieve this image was a digital Canon PowerShot SX530 HS, which comes stock with a 4.3 - 215.0 mm lens. The field of view of the photograph was about 4x4.5 inches. The camera was placed about 1 inch away from the glass jar. The exposure settings were as follows, aperture was set to F3.4, the shutter speed was 1/30, and ISO was set to 400. These settings were used to compensate for the low light environment. The original and final images are shown bellow in Figure 2. Post processing was done using Photoshop Elements 13. First the image was cropped to eliminate unwanted features. The original image was 3456x3456 pixels. After cropping the final image was 2651x2196. To enhance the image the contrast was turned up and the colors were manipulated by turning up the blue spectrum. I also used the paintbrush to hide distracting features in the background of the image.

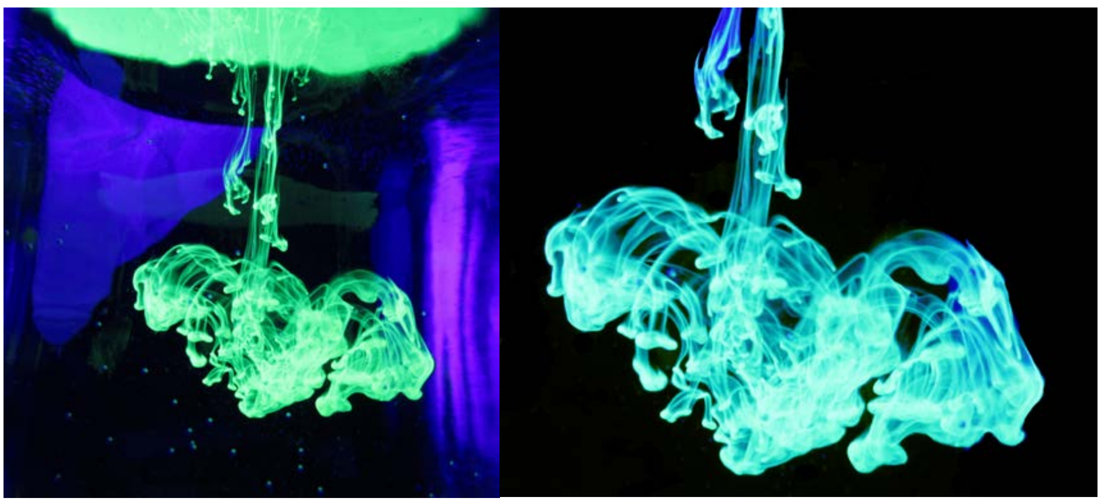

Figure 2 Pre and post image processing

Conclusion:

The image shows how a small amount of higher density fluid settles in a fluid of lower density. The Rayleigh-Taylor instability can be seen clearly, both in its initial laminar stage and also the developed unstable region. The biggest challenge in achieving this image was dealing with the low light environment. I wish I could have achieved better focus and resolution. To improve upon this experiment I would suggest using two blacklights surrounding the specimen to provide more light. I would also use a glass tank with a perfectly flat surface and minimal glass thickness; I believe the jar used to achieve this image may have created some distortion.

References:

[1] "The Chemistry of Highlighter Colours." *Compound Interest*. N.p., 22 Jan. 2015. Web. 25 Sept. 2015.

[2] "Highlighter Data Sheet." (n.d.): n. pag. *Dokumental*. 27 July 2011. Web. 24 Sept. 2015.

[3] "Rayleigh–Taylor Instability." *Wikipedia*. Wikimedia Foundation, n.d. Web. 25 Sept. 2015.