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Flow Visualizations
MCEN 4228-010

Assignment 3: Whirlpool

Whirlpools are a well known phenomenon that we experience anywhere from out on the water, in your kitchen, or in a middle school science demonstration. These appear bodyes of water as large scale eddyes that are produced by in interaction of rising and falling tides (3)(. Though visualizing the phenomenon in water allows us to see the general behavior of the fluid, there is much more going on that water is unable of show. The intent of this image was to visualize this additional behavior and display it in a way that anyone could be intrigued.

In order to capture the image, the right conditions need to be set up. A 16 oz. glass was filled nearly to the top with ordinary tap water. The dye used was neon food coloring gel mixed 2:1 with water to decrease viscosity. The conditions were simulated by swirling the fluid vigorously for about 15 seconds using a stirring rod. Once the desired motion was obtained, a few drops of the dye fluid was dropped into the center of the vortex. The picture was then taken by the camera approximately 2 ft from the glass at approximately 10° above horizontal (See Figure 1).

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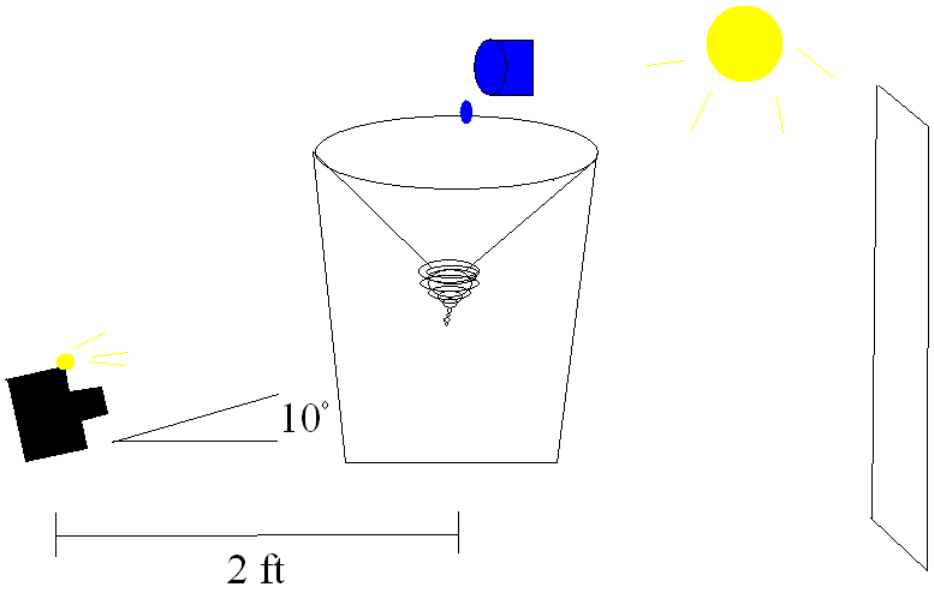

Figure 1 – Experiment Apparatus

Due to the nature of the phenomenon, motion blur was a concern. Because the fluid was stirred by hand, it reached a maximum velocity of no more than 20 inches per second at the top (based on the apparent RPM and the diameter of the cup). The flow nearly follows a free vortex, meaning the velocity of the fluid in inversely proportional to the distance from the center of rotation (1). This means that as the radius of rotation decrease, the fluid is increasing in velocity. Knowing this relationship, the maximum velocity of the fluid was approximated to be 100 inches per second. The shutter time was 1/200 sec for the photo, so using the rate of change equation below allowed the distance traveled during the shutter opening to be calculated.

$$\bar{\mathbf{v}} = \frac{\Delta \mathbf{x}}{\Delta t}.$$

Equation 1 – Rate of Change(2)

This was found to be .5 inches per second. Though this value is not sufficient for the entire image, a majority of the motion will be much less than that and will then be time resolved. The field of view was approximately 12” by 8”, with an image taken of 3872 x 2592 pixels. The pixel width was then .003 inches, which was definitely be a high enough spatial resolution for the image.

To visualize the phenomenon, a dye was placed into the moving fluid. The dye used is a typical gel food coloring which was diluted with water in order to increase fluidity with a ratio of 2:1. This dye was dropped into ordinary tap water. Because the fluid was in rapid motion, a very high shutter speed was needed to capture the image appropriately. Therefore, lighting was very critical to effective visualize the phenomenon. To accomplish this, a 60W light bulb was located about a food above and

slightly behind the glass. A piece of blank paper was mounted behind light to reflect more light as well as to act as a backdrop. Finally, the flash on the camera was used to get the final needed light.

The camera used to take the image was a Nikon D80 digital with a Nikon DX lens. As mentioned above the field of view is approximately 12" by 8" located about 2 feet from the end of the lens with a focal length is 52mm. The original image size was 3872 x 2592 pixels while the final image was altered to 1094 x 1052 pixels. The high fluid motion caused me to use a 1/200 shutter speed with an aperture of f/4.9 and an ISO rating of 100. Between the original and final image, very few changes were made. The image was first cropped to show the desired location from the field of view. The only other modification was attempting to eliminate the glare from the flash. This was done by highlighting the area around the glare and making it darker, followed by changing color setting to add more purple in order to blend in with the surrounding fluid. This was repeated until the glare was minimal. Though changing the colors drastically alters that region of the image, the glare itself was already showing nothing about the flow and was only a distraction to the viewer.

The final image (Figure 3) reveals additional flow characteristics of a typical whirlpool vertex. I like the clarity of the dye moving in the slower region on the outside of the vortex. This shows the behavior of the fluid in that region very clearly and how it is pulled into the vortex instead of mixing very quickly with the surrounding water. However, because the fluid is moving so quickly at the center of the vortex, it is a little difficult to visualize the behavior at that location. However, I do believe the physics of the overall behavior of the vertex are shown well in that the dye becomes trapped near the center of the vortex where the fluid is moving the fastest. You can see in the image that the dyed section appears to split in waves of paths that form cylindrical sections and the dye is concentrated. I would like to understand more as to why that happens to be able to better understand the image. The other part of the result I did not like was the glare that appeared on the front of the glass. The camera flash was very crucial to getting the right image, so some glare could be tolerated. Next time I would try to get more light without having to use the camera flash, which would eliminate this problem. The image is a great side view of the phenomenon, and to go further I would like to view the vortex from above to see what else that can tell about the fluid behavior.

Works Cited

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(2)
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(3)
"whirlpool**."** Encyclopædia Britannica. 2009. Encyclopædia Britannica Online. 10 Mar. 2009

(4)
"Whirlpool Facts and Myths." Divnick International, Inc. (1985-2009). 10 Mar 2009.
http://www.spiralwishingwells.com/guide/images/whirlpool2.jpg

Appendix A

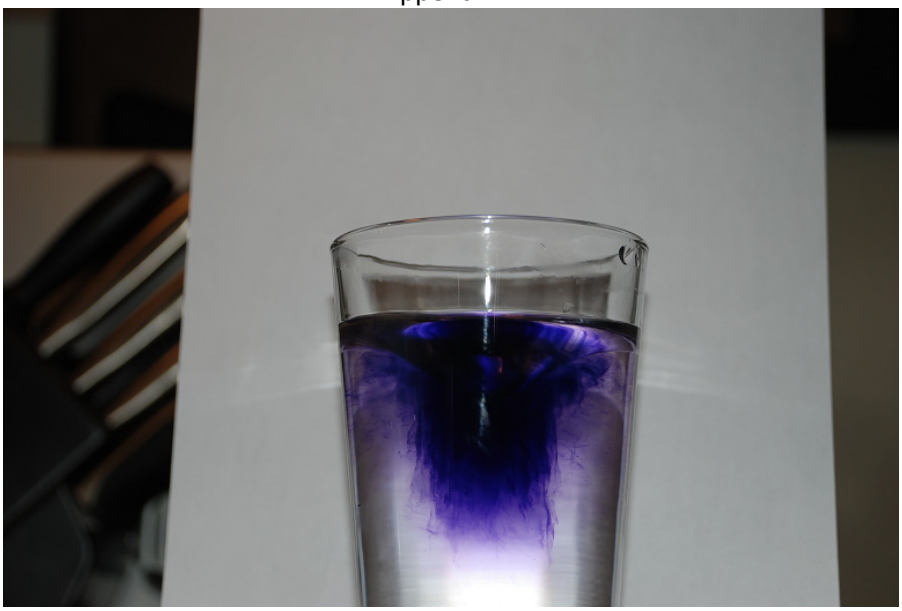

Figure 2 – Original Photograph

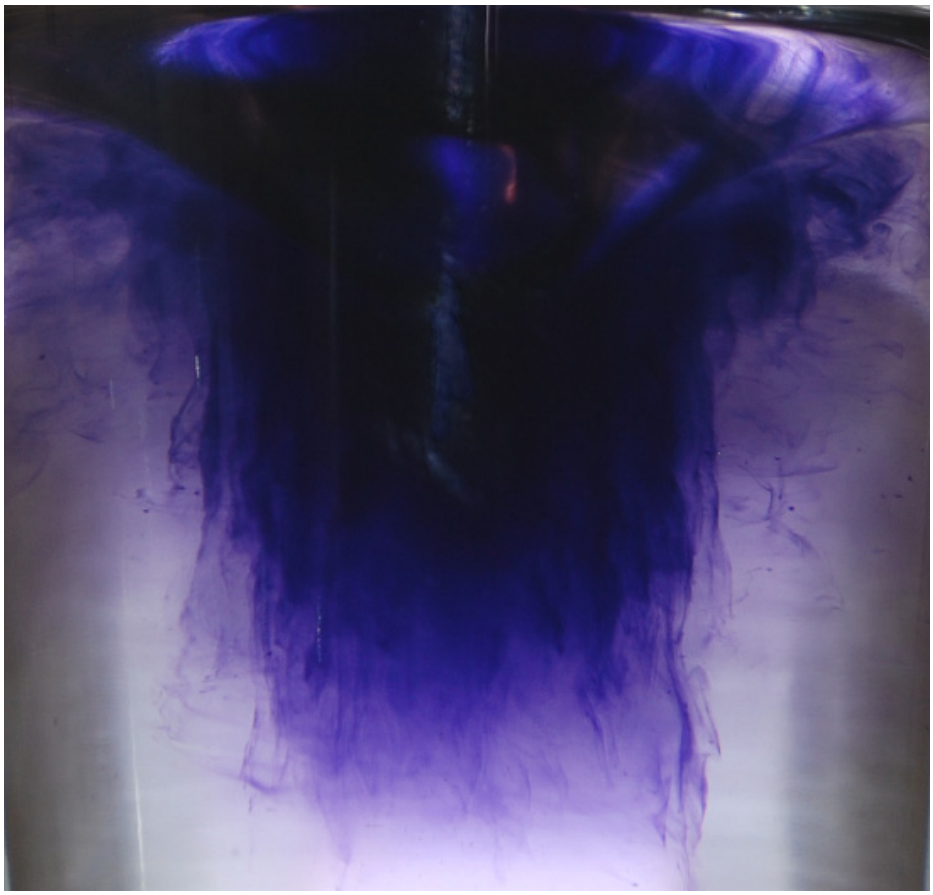

Figure 3 – Final Image