2011

Flow Visualization – Team Project 3

MCEN 5151

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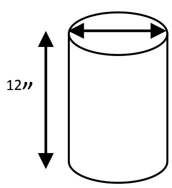
For the third and final team project assignment we wanted to explore the behavior of whirlpools. To make these observations more interesting we wanted to work with fluorescent materials that glow under UV light. Everything was occurring under a controlled environment and thus our whirlpool was manually created. The set up we used proved to be more difficult that we initially expected, but I think we were still able to achieve our ultimate goal of showing the motion of a fluid when introduced into a whirlpool.

Since we were observing materials under UV light, our light source was a common black light. To create the whirlpool effect we were looking for, we used an electric egg beater. This created a nice whirlpool vortex in the vase. To capture this flow we removed the egg beater and quickly took pictures before the vortex dissipated. Instead of a perfect cylinder as shown below, we had a vase with a smaller circumference around the middle than compared to the top and bottom.



2

The vase was 12 inches tall with a diameter at the opening of about 4 inches. I believe the shape of the vase ultimately led to a quicker dissipation of the vortex each time. The operation for creating and observing this flow was to submerge the egg beater in the vase for roughly 10+ seconds. Upon withdrawing the egg beater from the vase, some fluorescent tracer was immediately poured in. The fluorescent tracer (laundry detergent in my case) was captured by the vortex and immediately spun around.

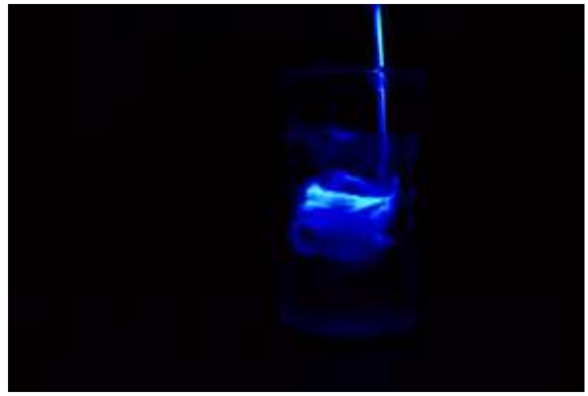


Figure 1: Original Vortex Image

Black lights got their name because the human eye cannot perceive the UV light that is emitted by them. The use of fluorescent materials allows us to see the effect of this UV light. The UV light is absorbed by the laundry detergent in this case. Almost simultaneously the absorbed light is emitted by the detergent at a lower, visible frequency.[1] The resulting visible frequency that is emitted is what is observed in the image show in Figure 1. When observing the vortex in the time sequence, we can see that the depth of the vortex becomes shallower as time increases. This is a direct result of the vortex decreasing in rotational velocity. This type of vortex is known as a free or irrotational vortex. The tangential velocity of this type of system is

$$v_\theta = \frac{\Gamma}{2\pi r}$$

Gamma (Γ) represents the circulation and r is the radius of the vortex. In this case since the vase diameter is 4 inches, r = 2 inches. The denominator of the above equation is a constant and thus the only value changing is Γ. Circulation is calculated using the following formula.[3]

$$\Gamma = \oint_C V \cdot dl$$

As the velocity V changes, the tangential velocity also changes.

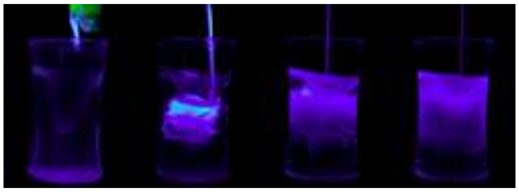


Figure 2: Final Time Sequence

To better visualize the flow we used fluorescent tracers under a black light. Initially we hoped to use gin as our base liquid. Since gin contains quinine it glows under UV light. Ultimately we used plain tap water as our base liquid and then poured a small amount of laundry detergent into the whirlpool. The lighting for this project was very interesting. Normally black light provides enough light to see fluorescent objects. However, when those objects are in motion it is a different story. All lights in the room were turned off except for the black light. Since the water in the vase did not glow under UV light, there was not much UV light being reflected. Once the laundry detergent was added, the amount of light being reflected increased dramatically, making it easier to capture something in motion. A flash could not be used for this part because it would reflect off the vase as well as wash out the fluorescent colors that we were trying to capture.

The capture a good time sequence of images, the camera was set up on a tripod. The maximum capture rate of my camera is 4.3 frames per second. So it can be assumed that each of the images in the sequence is 1/4 s apart. The field of view of a single image was roughly 36 inches wide and 24 inches tall. Since the light conditions were low, I needed to use the largest aperture possible. To get the largest aperture possible, the focal length needed to be as short as possible. Thus the camera was positioned about 2 feet from the vase. The focal length was set to 32.5 mm but this still allowed for an aperture value of f/4.0. The camera being used was a Pentax K2000 DSLR which was set to aperture priority. The ISO was set to auto with a limit of 1600, and naturally in the low light conditions ISO 1600 was used. I would have liked to avoid such a high ISO, but it was the only way to achieve a decent image given the light conditions. The final image is composed of four individual images. Each individual image had an original size of 3872 x 2593 pixels. Each image was first cropped down to a size of 1600 x 573. Then, when brought together to form the time sequence image, the final image had a size of 6400 x 2292 pixels. Since the shooting mode of the camera was set to aperture priority, the shutter speed was variable. In the first image, when laundry detergent had not been added to the water, there was less light. This resulted in a shutter speed of 1/6 s. As the detergent was added and the camera started to adjust to the extra light, the shutter speed was increased to 1/30 s. During the last two images taken, the laundry detergent was fully present in the water and the camera had adjusted to a shutter speed of 1/45 s. I found this to be interesting but not fully unexpected. It is fairly obvious from the final image that photoshop was used to create it. As stated above, each image was cropped down to the same size. Then all four images were brought together into the same image. Since the ISO was high, there were some grainy elements around each picture, so the paint brush tool was used to make the background a solid black. Next, a red filter was applied to the bright blue to produce a purple image. This seemed to bring out more of the details in the vortex.

This image reveals information about UV light as well as the physics of a whirlpool. I liked the original vibrant blue of the image. The reason for the color change was an attempt to bring out more detail in the fluid. I was disappointed with how little light was available from the black light for shooting. Perhaps with more black lights it would have been easier, but unfortunately we only had access to one. The first two images do provide a decent visualization of a vortex, but it could be better. Overall I am satisfied with this image and if nothing else, it is at least somewhat artistic and colorful.

References

[1] Helmenstine, Anne Marie. "Materials That Glow Under Black Light." *Chemistry*. Web. 27 Apr. 2011. <http://chemistry.about.com/cs/howthingswork/f/blblacklight.htm>.

[2] http://www.clipartguide.com/_pages/0060-0709-2717-3662.html

[3] Robert W. Fox; Alan T. McDonald; Philip J. Pritchard (2003). *Introduction to Fluid Mechanics* (6 ed.).