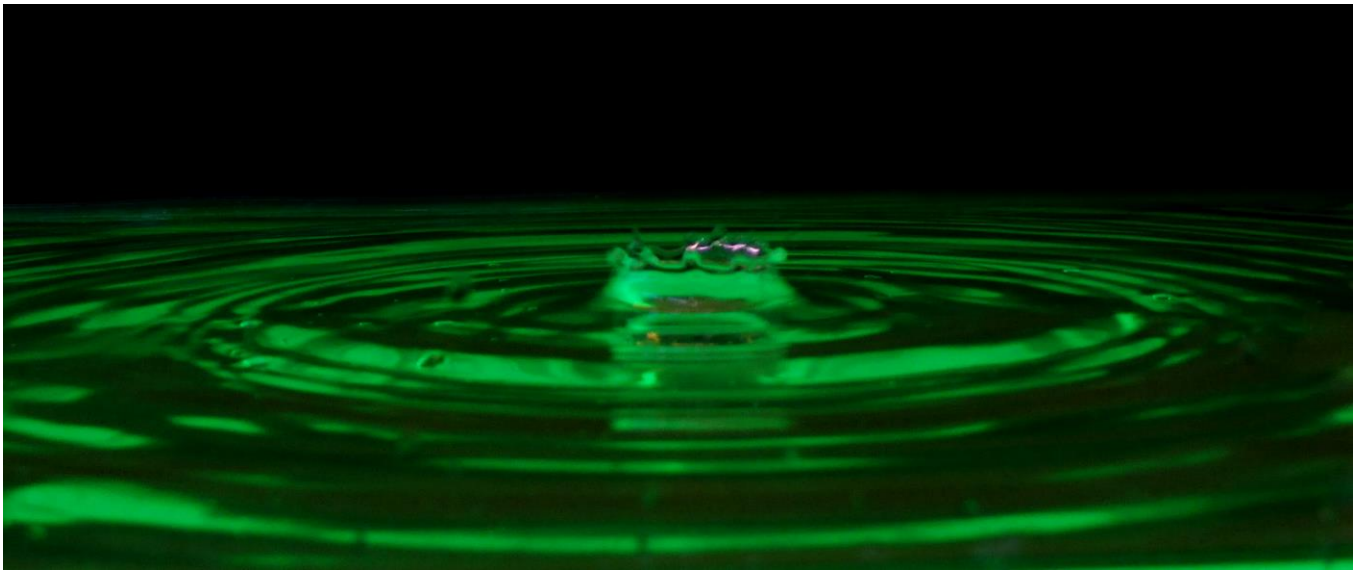
Flow Visualization: Team Photo 2



MCEN 4151: Flow Visualization
April 04, 2013
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Purpose

Initially the team wanted to photograph the double-slit phenomenon but had trouble lighting and capturing the necessary wave formations. We decided to dissolve highlighters into water, so we could create a glowing green appearance that would capture florescent light reflection. We noticed that with the highlighter and water mixture, we could produce very intriguing images of water droplets. We took many images of variations of crowning craters and Worthington jets. For this image, I chose the point when a water droplet impacts a water surface and creates a crown. The image was made possible with the help of three team members: Gaberiel Bershenyi, Jennifer Milliken, and Zachary Brunson.

Flow Apparatus

The flow apparatus consisted of a basic 20 gallon fish tank (24" long x 13" wide x 17" tall). It was filled with roughly 1" of a highlighter and water mixture. The image was taken from the wide side, 24" side. The back side of the tank had a piece of black cloth as a back drop. The tank was sitting on a white sheet of acrylic. Two 24" fluorescent aquarium lights were used for lighting. One light latched on to the top of the fish tank and the other was placed on the left side, 13" side, perpendicular to the camera's line of sight. These were the only two lights present in the room. The water droplet was produced using a standard syringe and was dropped directly perpendicular to the water's surface from a distance of about 15". The droplet was 4 mm. Two schematics of the flow apparatus are shown below.

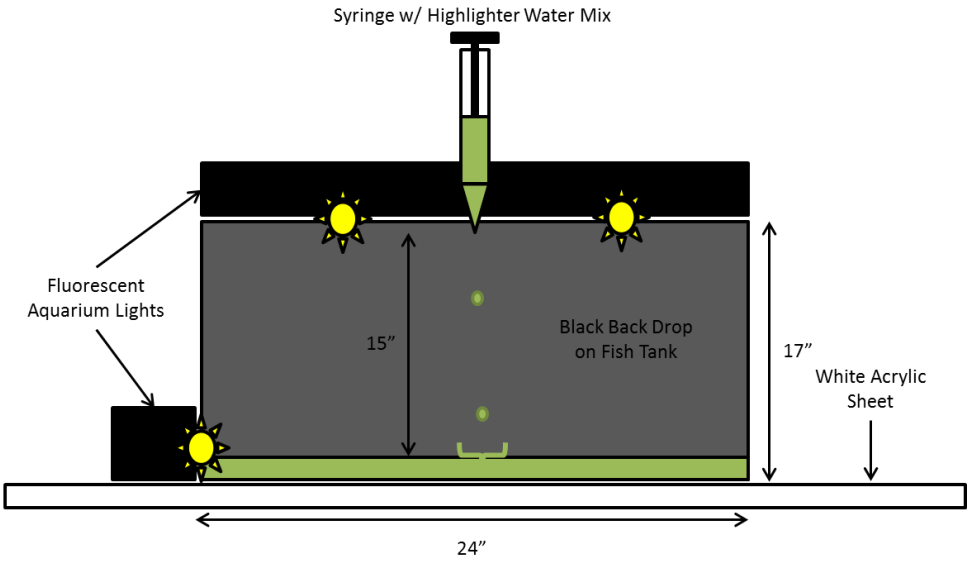

Figure 1: Flow Apparatus from Front / Camera Perspective

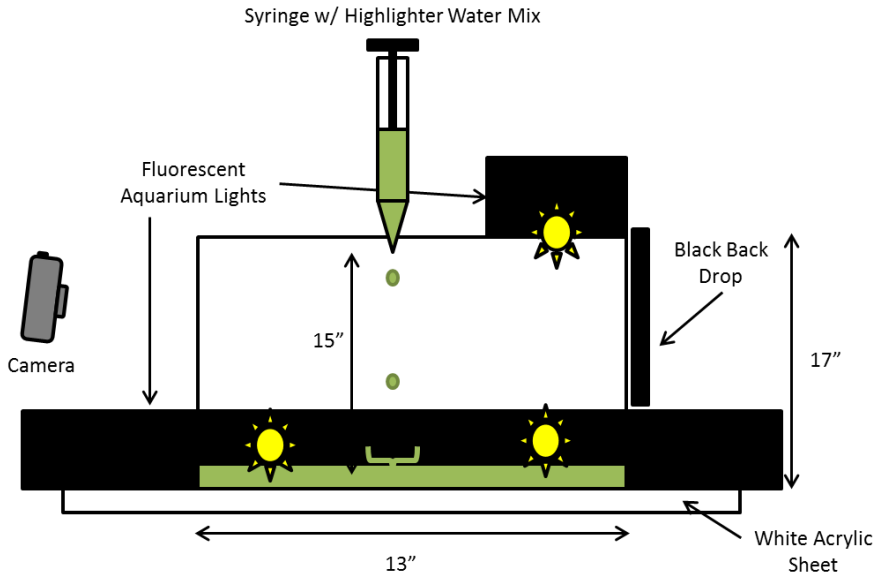

Figure 2: Flow Apparatus from Side

Flow Dynamics

When droplets impact a fluid surface, they initially push the impacted fluid away forming a crater surrounded by crown-like ejecta. A Worthington jet rises from the collapsing of the crater quickly after. The basic concept is fairly simple and can be observed in almost every droplet impact. The figure below better shows the impact progression.

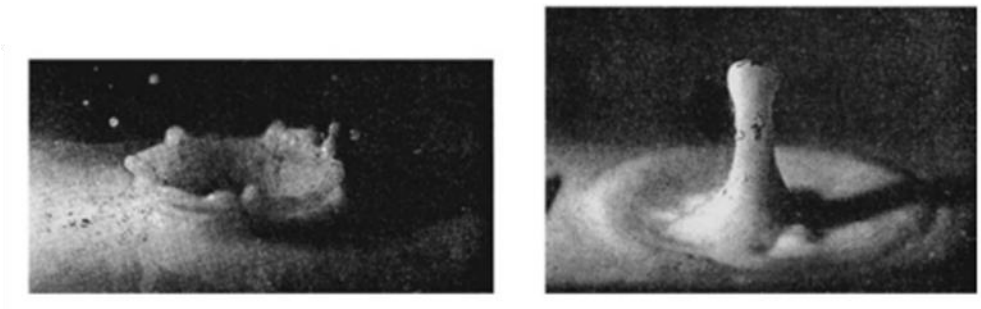

Figure 3: Crown (left) followed by Worthington jet (right)[1]

The Reynolds number can be used to better understand the physics of the presented flow phenomenon. Reynolds number is calculated:[2]

$$Re = \frac{\rho * V * d}{\mu} = \frac{U * D}{v}$$

where U is the velocity of the droplet, R is the radius of the droplet, and v is the viscosity of the droplet.

U was estimated to be roughly 2 m/s. The diameter of the droplet was measured to be about 4 mm. The viscosity of the water is about 1.0 X 10^-6 m^2/s.[3]

$$Re = \frac{2\frac{m}{s} * .004m}{1.0x10^{-6}\frac{m^2}{s}} = 8000$$

This Reynolds number describes a fluid in turbulent flow which is to be expected from a droplet in free-fall.

Another meaningful number is Weber's number:[4]

$$We = \frac{\rho * V^2 * d}{\sigma}$$

Where ρ = 1000 kg/m^3, V = 2 m/s, d = .0035 m, and σ = 72 x 10^-3 N/m[5].

$$We = \frac{1000\frac{kg}{m^3} * 2\frac{m^2}{s} * .004m}{72\ x\ 10^{-3}\frac{N}{m}} = 222$$

This We number describes a regular crown which is what was observed. Refer to the figure below.

Figure 4: We Number Relation to Crown Shape[1]

Visualization Technique

Several techniques were utilized to obtain the image. Since the droplets were followed one after another, we had to experiment with the different disruptions in the water surface. We tried to space the droplets out so that disruption was minimized. Also, after about 10 drops, the glass of the tank between the camera and impact would get wet and distort the images. We wiped down the glass very often. We also placed a piece of wood in the tank on the right side to allow for better focus. Since we were using a highlighter mixture and only a couple fluorescent lights, it was very difficult to capture enough lighting, but could be achieved with the right camera settings. It was also important to drop each droplet steadily in the same spot. In order to do this, I used both hands to stabilize the dropper as Zachary Brunson took the photograph. Each technique was easily achieved but crucial to the success of the image.

Photographic Technique

The photographer of the image was Zachary Brunson. The camera used was a Canon Canon PowerShot SX500 IS (16 megapixels).[6] No flash was used. The ISO was set at 100 to reduce noise within the image. The shutter speed was set to 1/200 of a second which captured a quick shot of the very fast-occurring impact. Aperture was f/3.4 which allowed an effective volume of light to enter the lens.[7]

I did all of the post processing utilizing Photoshop. The image was cropped to focus on just the crown. The contrast curves were adjusted to reduce noise and enhance the black and green contrast. Slight touch ups were made using the spot healing tool to remove droplet marks on the glass of the tank and blacken the background.

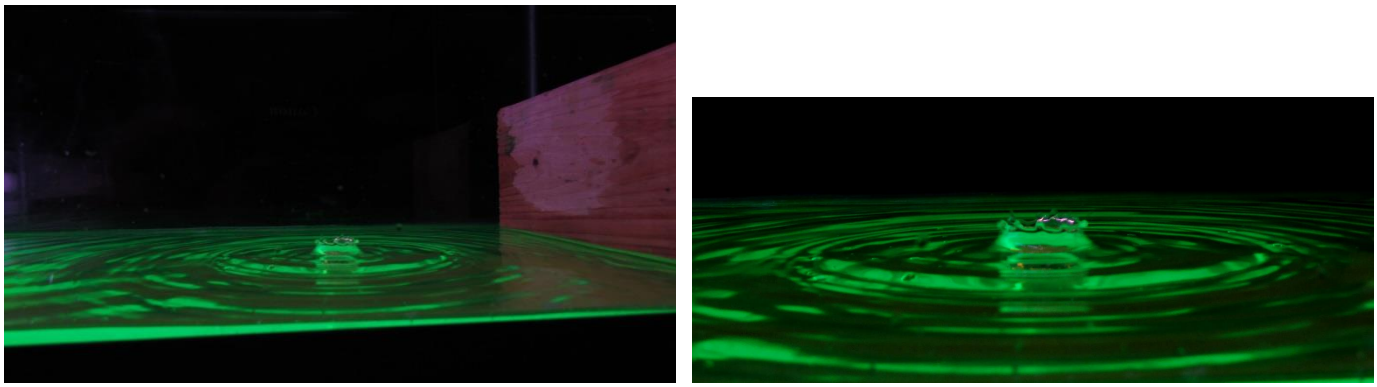

Figure 5: Before (left) and After (right) of Image

Conclusion

Producing a crown and a Worthington jet is not very difficult. However, capturing a good image can be difficult and take a lot of time and repetition. Timing the photo is everything, so it is necessary to take a large quantity of photos. With the right setup, simple droplet impacts can produce amazing flow visualizations. I found this image and experiment to be successful and amusing.

References

[1] http://www.annualreviews.org/doi/pdf/10.1146/annurev.fluid.38.050304.092144

[2] "Reynolds Number ." Engineering ToolBox. N.p., n.d. Web. 14 Mar. 2013. <http://www.engineeringtoolbox.com/reynolds-number-d_237.html>.

[3] " Water - Dynamic and Kinematic Viscosity ." *Engineering ToolBox* . N.p., n.d. Web. 12 Feb. 2013. <http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html>.

[4] http://www.engineering.ucsb.edu/~rkrechet-lab/files/publications/jcis2009.pdf

[5] http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html

[6] &. "Amazon.com: Canon PowerShot SX500 IS 16.0 MP Digital Camera with 30x Wide-Angle Optical Image Stabilized Zoom and 3.0-Inch LCD (Black): CANON: Camera & Photo." Amazon.com: Online Shopping for Electronics, Apparel, Computers, Books, DVDs & more. N.p., n.d. Web. 2 Apr. 2013. <http://www.amazon.com/Canon-PowerShot-Wide-Angle-Stabilized-3-0-Inch/dp/B00908BMVE>.

[7] "Exposure | Understanding Exposure - ISO, Aperture and Shutter Speed Explained." ExposureGuide - Photography Tips, Techniques and News. N.p., n.d. Web. 14 Mar. 2013. <http://www.exposureguide.com/exposure.htm>.