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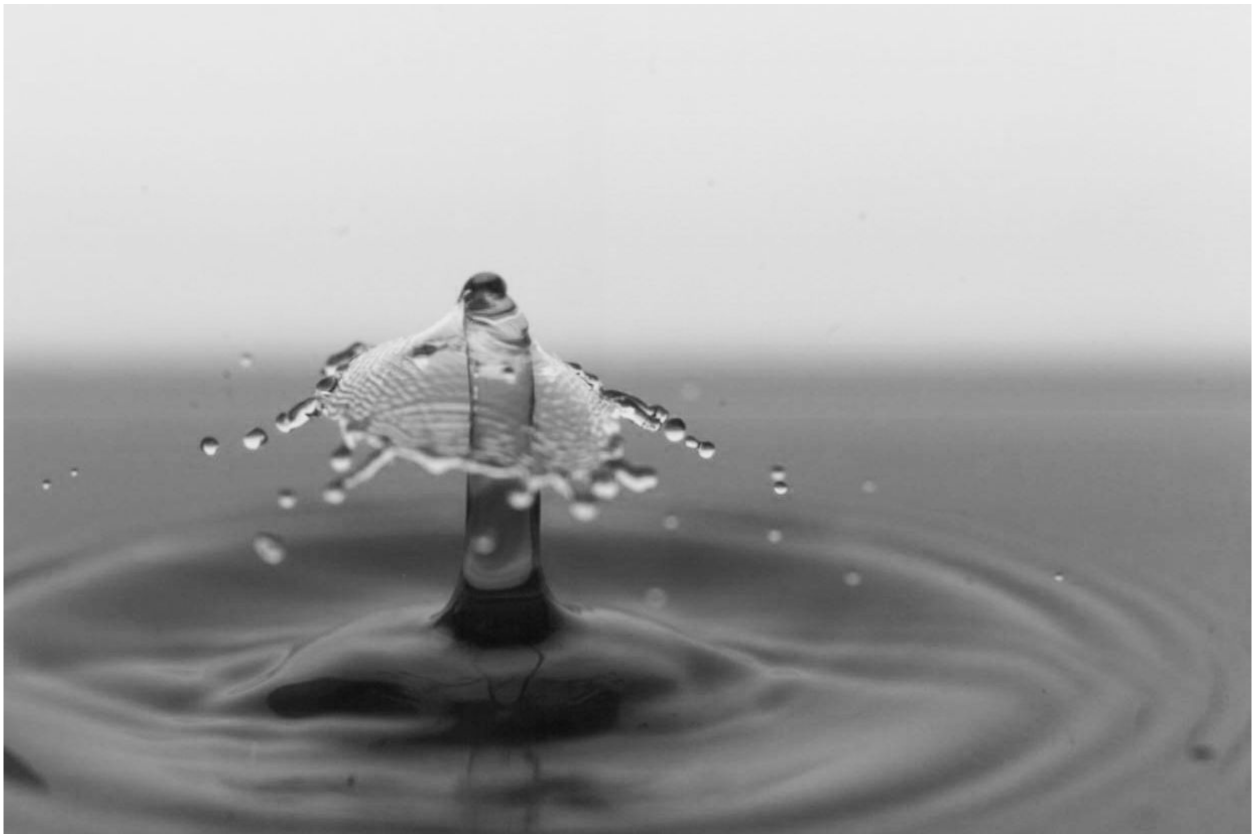
Jean Hertzberg
Flow Visualization

Team Second Image: Worthington Jet



Team 8: Danny Baker, Brett Sibel, Marcus Gurule, Theo Petrides

Introduction

For our second team images, we wanted to get photographs of water droplets splashing into a water basin. To do this, we used Project SplashDrop, provided by Kyle Walters and and Kyle Hollis. They two created the setup for an independent study class by Professor Hertzberg. The creators of Project SplashDrop only have us the materials and documentation, and it was our prerogative was to set it up with minimal assistance.

The goal of using this setup was to capture a Worthington Jet. This jet is formed when a water droplet hits a solid or liquid surface. To capture this image a Phantom camera was provided by Professor Tadd Truscott from Utah State University. This camera allowed from slow motion videography to capture the drop at the right timing.

Procedure

The documentation for the setup of the project starts with a Quick Start Guide. This guide outlines an kit inventory that includes a project box, seven frames, three solenoid valves, and two flash diffusers. Not included in the kit, but needed for the experiment is a camera, tripod, camera remote release cable, and a water basin.

To begin we assemble frames 1 and 3 by attaching them to the T-shaped pieces of frames 2 and 4. Next we attached frames 5 and 6. These are interchangeable and act as mounts for the valves which can be arranged with any height variation and angle adjustment. Finally, frames 5, 6, and 7 will be the crossbars of the two legs with five being the bottom and 7 being the top. We had to rotate frame 7 a bit to makes sure the reservoir clamp was away from the frame to slide it into the clamp. The final assembly should look like figure 1 below.

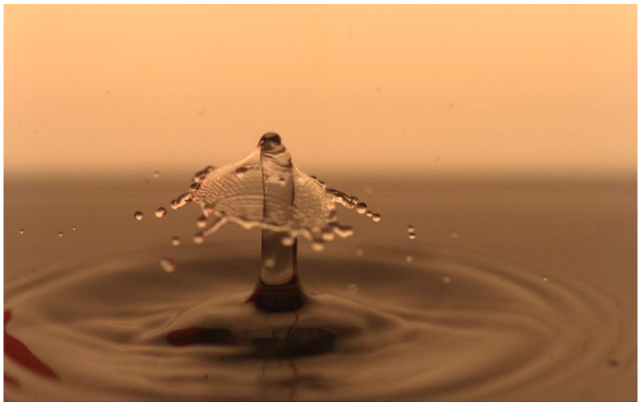
Figure 1: Fully-assembled frame

Afterward we filled a water basin, nearly to the top, with tap water and placed it under the frame. Fog lamps were then placed behind the assembly, with one being on the left and one on the right. We placed a red see-through sheet on the left light to give the basin more color. We can set up the tripod in front of the assembly ready to photograph.

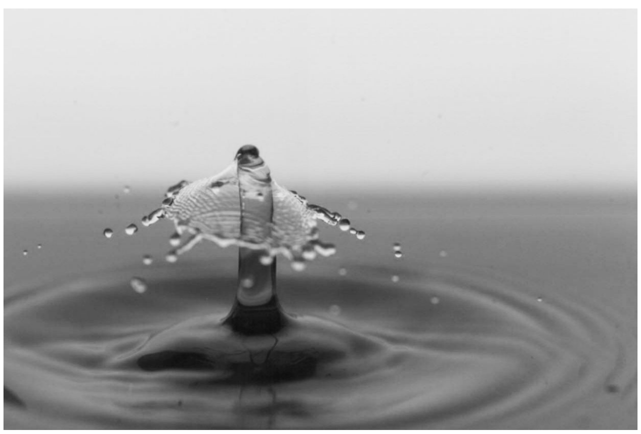
Finally, it was time to connect the Android application to the system. The app itself was called dropControllerBT and used on Kyle Walters cell phone. We set the droprate to be *something*.

Once we pressed go on the app, it was time to take the slow motion video. The app layout is shown in the appendix.

Unedited Image:



Edited Image:



Camera Settings:

The camera used was a phantom slow motion video camera. The camera was set up and took a multitude of photographs before and after the drop was completed. This have use a window of time that allowed to drop to take place. We would then look through the video in slow motion and take a screenshot of our favorite image. A photograph of the camera is the first photo in the appendix.

Post Processing:

The post processing for this image was fairly basic. First, the photo was cropped down to only include capillary waves and the worthington jet itself. The rule of thirds was tried to be used in this photo. This is why the jet is moved to the left. The image itself wasn't large enough to move the jet far enough over to make a perfect rule of thirds. Next, the brightness and contrast on the image was increased. Finally, a black and white filter was placed over the whole image. This was to take away the awkward yellow glow.

Worthington Jet:

According to Jenna McKown, Worthington jets result from "the impacts of hydrophobic and hydrophilic sphere with the free surface" (McKown). Viscosity is known to be fairly negligible where there is a strong dependence on gravity in hydrophilic cases. Alternatively, in hydrophobic cases, the lifespan of the jet itself is linearly dependent on the Frounde number. In this case, the Worthington jet was created in the hydrophilic case.

The Froude number can be found by using velocity of the sphere on impact (Uo), the diameter of the sphere (D), and gravity (g). We know that gravity is 9.81 m/s^2. We can estimate that the diameter is approximately 1 cm, and the speed at impact was approximately 3.5 m/s. Using the equation below we can approximate the Frounde number to be 11.17.

$$Fr = \frac{U_0}{\sqrt{gD}}$$

Capillary Waves:

Capillary waves are formed in the image moving out circularly from the impact zone. Capillary waves, more commonly known as ripples are formed when a boundary layer has its dynamics dominated by the effects of surface tension. These waves typically have "very short wavelengths (millimeters or centimeters), the restoring forces of water waves in surface tension". This phenomenon can be described by the dispersion relation below. The variable γ can be described as the surface tension parameter.

$$\omega = \sqrt{k\,(g + \gamma k^2)\,tanh(kH)}$$

Conclusion

Overall, I am very happy with the image. Without the Phantom slow motion video camera, the image would not have turned out nearly as well. I also love the black and white aesthetic. One thing I possibly would have changed would have been to control the droplets better. If there was no droplet to fall on top of the jet as it extended it would look a little more clean. Even with that said, this extra droplet does give the image something different from most Worthington jets.

Acknowledgements

I would like to extend a thank you to Kyle Walters and Kyle Hollis for letting our team use their SplashDop setup.

References

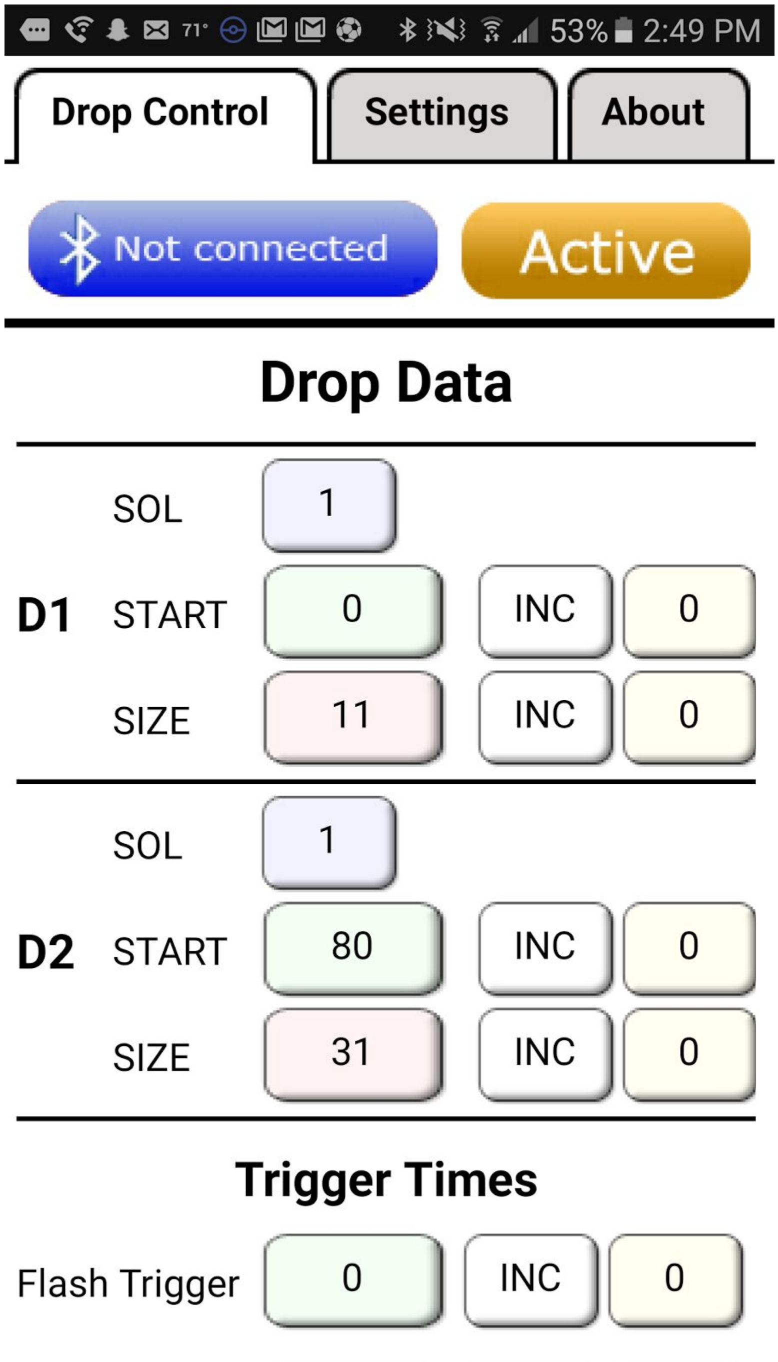
"Capillary Waves." Chapter 4: Waves. Dartmouth University, n.d. Web. <https://engineering.dartmouth.edu/~d30345d/books/EFM/chap4.pdf>.

McKown, Jenna Marie. An Experimental Study of Worthington Jet Formation After Impact of Solid Spheres. Tech. Boston: Massachusetts Institute of Technology, 2011. Print.

Walters, Kyle, and Kyle Hollis. SplashDrop. Boulder: U of Colorado, 2016. Print.

Appendix


VISION RESEARCH
AMETEK
VISION
PHANTOM
B-REF
TOOLS
PLAYBACK
MENU
v2511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Drop Control
Settings
About
Not connected
Active
Drop Data
D1
SOL 1
START 0 INC 0
SIZE 11 INC 0
D2
SOL 1
START 80 INC 0
SIZE 31 INC 0
Trigger Times
Flash Trigger 0 INC 0