# Double Slit Interference Visualization

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## I. Introduction

THIS experiment was an attempt to visualize a Worthington jet and water droplet crown on high speed video. The goal was accomplished by using a hand held high speed camera to record two droplets falling into a pool of water in quick succession. The timing of the two droplets was controlled by a microcontroller and servo valve such that the second droplet would impact the Worthington jet at its peak and create an impact crown.

The experiment was designed as part of the Flow Visualization class at the University of Colorado at Boulder. In this class, undergraduate and graduate students from multiple disciplines produce experiments to capture images that demonstrate both aesthetic beauty and interesting physical phenomena.

## II. Flow Apparatus

This image was created with the use of a microcontroller and servo valve that released two water droplets at a prescribed interval in order to create a Worthington jet and splash crown. An Arduino development board was programmed to control a servo controlled valve that released droplets from a pressurized water reservoir. The pressurized reservoir was used to achieve droplets large enough to separate from the nozzle, and not to add any velocity to the flow. The timing of the droplets was controlled such that each droplet formed over 120ms with a delay of 30ms between each. The droplets fell from an initial height of 17in into a black bowl of water that was 6.25x6.25in, and filled to a depth of 2in of water.

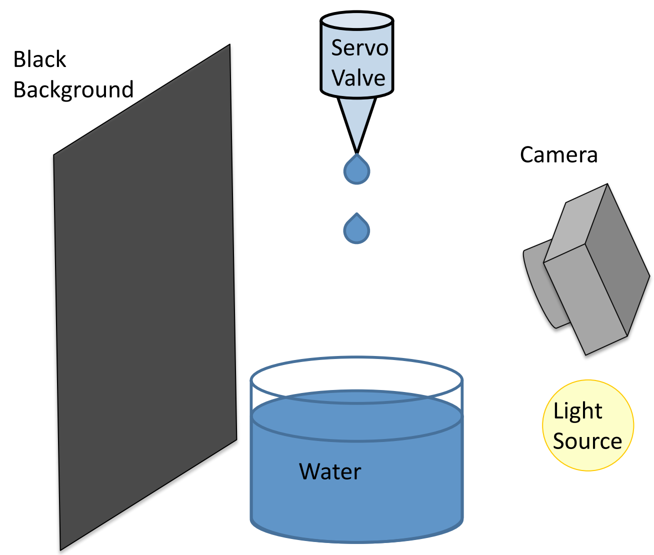


**Figure 1: Visualization setup**

[1] Student, MCEN 515 - Flow Visualization: The Physics and Art of Fluid Flow

## III. Visualization Technique

For aesthetic effect, a pearlescent indicator, Pearlex, was added to the bowl of water. This indicator had the added benefit of showing disturbances in the water. Thus, when the droplet fell into the motionless pool of water, the turbulent flows that it induced could be easily seen by the changing reflections and highlights in the Pearlex. Unfortunately, one cannot see any of the fluid motion within the jet itself because the concentration of the particles was not high enough to be an effective flow indicator within such a small volume of water.

The light source used was a single work lamp. This provided the incandescent spectrum that gives the image its warm characteristic. In order to achieve the best light scattering from the Pearlex, the work lamp was held at an angle of about 15 degrees above the surface of the water, and just to the right of the camera.

## IV. Flow Analysis

As a falling object impacts a surface of water, it is possible to create a Worthington Jet. This jet is the effect of an air cavity that forms in the wake of an the impacting object as it pushes beneath the surface of the water.[3] As this air cavity collapses, the water rushing to fill its place is forced upward with enough velocity to exceed the original surface level of the water and create the characteristic column shape of a Worthington jet. The formation of the air cavity is critical to the Worthington jet, but it will not happen for all impacting objects. For each object, there is a critical velocity, $v_c$, required to cause the air cavity formation as it impacts the water.[2] In a keystone analysis of the formation of Worthington jets, Duez et al showed that the critical velocity is dependent on the "wettability" of the surface of the impacting object.[2] Because the water cannot remain attached to a hydrophobic object as easily as it can to a hydrophilic object, the air cavity will form at lower speeds with a hydrophobic object.

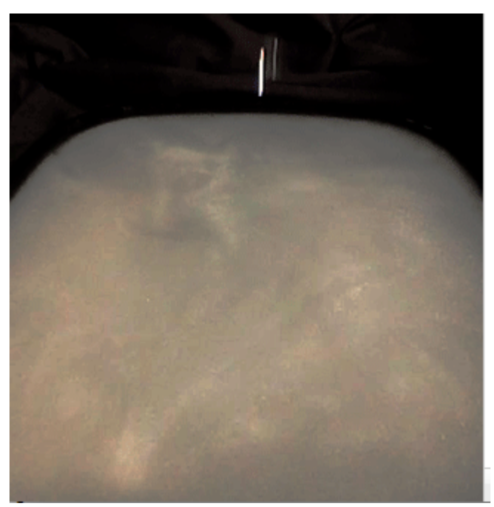
**Figure 2: Streak length at 240fps**

In this experiment, the impacting object was a drop of water, so the air cavity that forms is more like a crater in the water, and the critical velocity is on the order of 1m/s.[4] It is possible to calculate the velocity of the impacting droplet by using the work-energy relationship in the equation, $v=\sqrt{(2gh)}$, can estimate the velocity of the droplet based on the height from which it was dropped. The measured drop height of 17in results in a velocity of 2.9m/s as the droplet impacts the water. This agrees with the velocity estimated by a 0.5in motion blur streak at 240 frames per second, which indicates a velocity of 3m/s.

While the drop velocity of the drop is important to the Worthington jet formation, the dimensions of the impacted water pool are not relevant. That is because it has been demonstrated that the formation of the jet is independent of the depth of the impacted liquid and the size of its container.[1]

## V. Photographic Technique

The series of images was captured using a Casio Exilim EX-ZR100 point-and-shoot digital camera. The images were captured using the high-speed video function of the camera, which captured the motion at a rate of 240 frames per second. Because of the high frame rate, the video could only be captured at a size of 432x320 pixels. This low pixel size means that the image is not completely spatially resolved and could be improved by using a purpose built high-speed camera. However, for the intent of a GIF image suitable for distribution on the Internet, this image size is sufficient.

The video was edited with the Adobe Photoshop software tool. The original video was cropped to a size of 300x320 pixels to eliminate some of the extraneous black background from the frame. This image was then color edited using the curves function to increase highlight definition in the bright pearlescent water and eliminate all definition in the black background to increase focus on the water. This process worked to increase the highlights in the Pearlex, but may have increased the noise levels of the image. A comparison between the

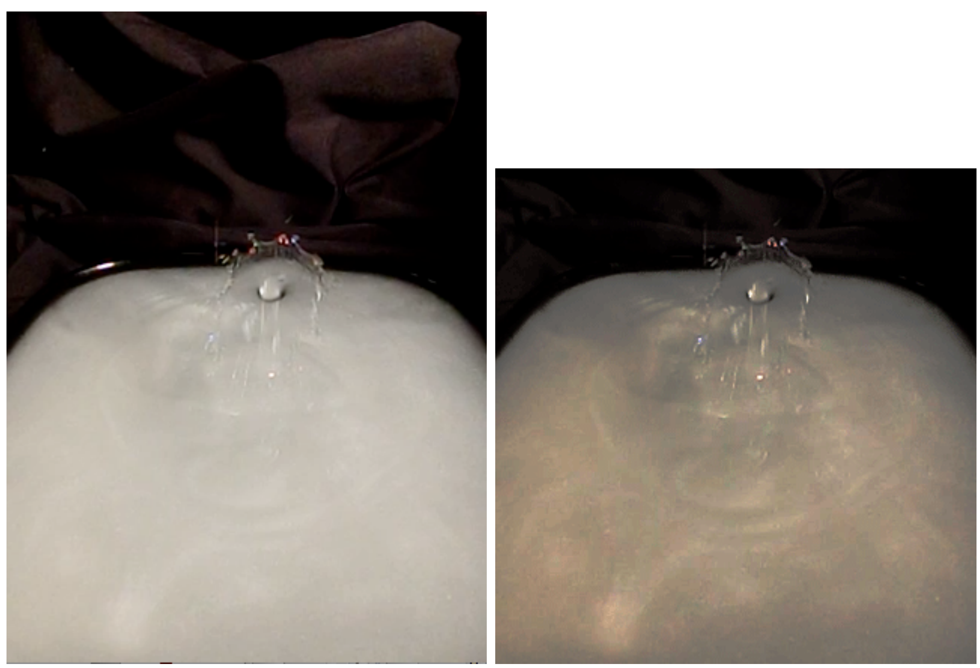

Figure 3: Image alteration comparison

original and final images can be seen in Figure 3.

## VI. Conclusion

The image in this report achieved the goals of capturing a Worthington jet and water impact crown in a video format that is easily distributed on the internet. It was found that the Worthington jet formed based on an impact crater on the surface of the water, which collapsed to release the jet. This sequence was captured in the GIF image sequence, but a higher resolution image using a specialized high speed camera would show more detail of this formation process.

## Acknowledgments

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## References

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