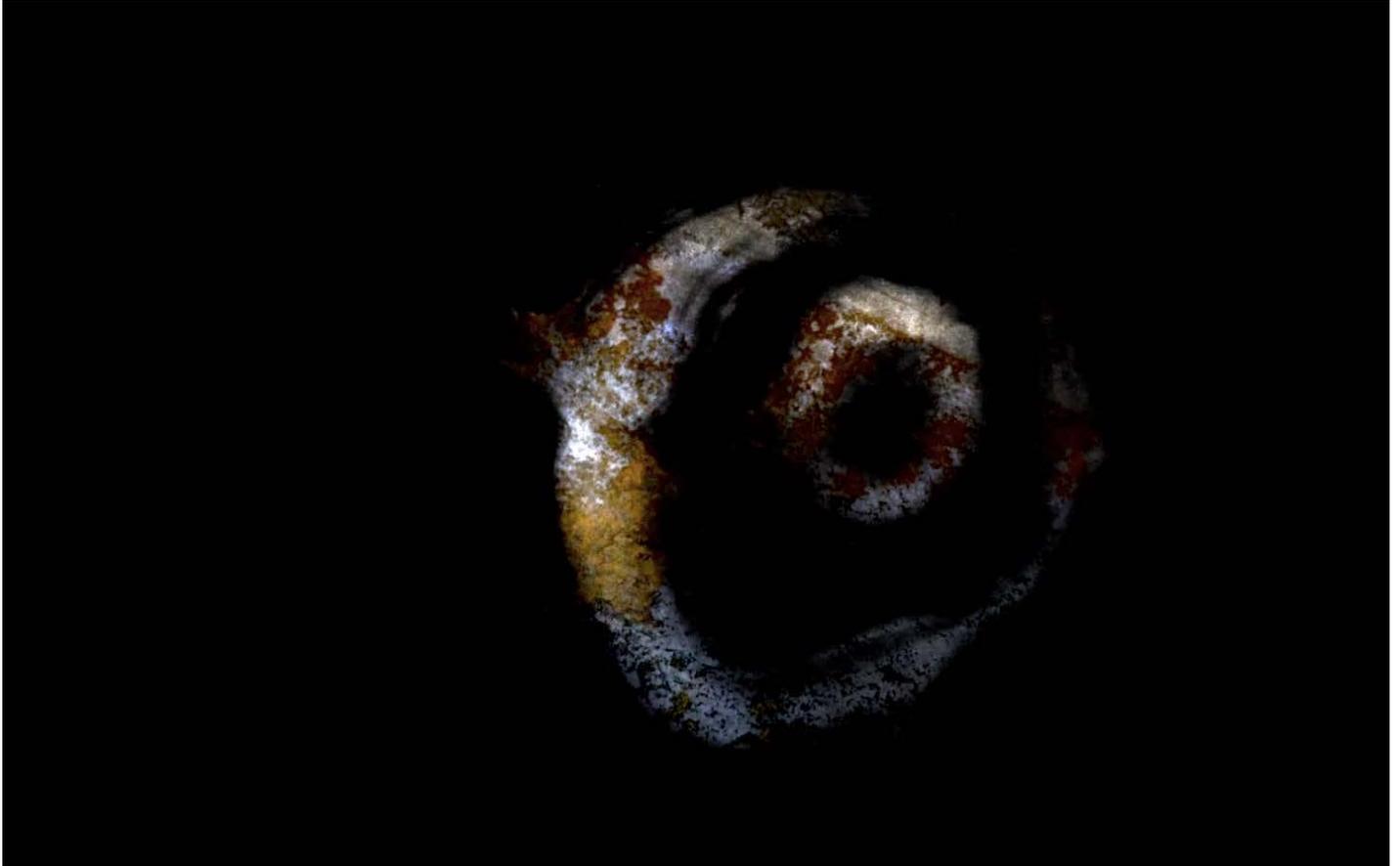


Lael Siler

Flow Visualization group project # 1



Introduction

Our first group project in Flow Visualization 4200 was making and visualizing smoke rings. Originally our group intended on making rings underwater that were colored with food dye and collided but found that making rings out of smoke would be a more manageable project for William Derryberry, Kristopher Tierney, Mark Voll, and myself's first time working together. We were able to use a very small amount of materials to generate beautiful images of smoke rings that are fascinating watch unfold from a cardboard box and dissipate into the air. My only previous experience with smoke rings had been at a hookah bar where by gently cranking my jaw backward, I could produce a ring of smoke in a room with still air. This time, we would create a box that would accomplish the same thing my mouth could, but on a much larger scale.

Description of Flow Physics - Written by Kristopher Tierney

Smoke rings are a clear example of a fluid dynamic phenomena known as a toroidal vortex, or more simply a vortex ring. This phenomena occurs when a circular disk of fluid is jerked normal to its plane and subsequently moves through a uniform, relatively stationary fluid medium^[1]. Once this disk is in motion, shear forces within the disk take over, and begin to form a ring. This is caused by the relative difference in viscous friction between the outer and inner radii of the vortex ring. As the ring progresses through the stationary fluid, viscous friction slows the outer layer of fluid relative to the rest of the ring. As this happens, the inner, faster fluid catches up, and forces the slower fluid out of the way, taking its place. Subsequently, the slower fluid reaches the back of the vortex ring, where there is a low pressure zone caused by the continued velocity of the fast fluid. Once the slow fluid reaches this low pressure zone, it is quickly converted into the new fast fluid, and the process repeats itself.

¹ Batchelor, G.K. (1967), *An Introduction to Fluid Dynamics*, Cambridge University Press

Experimental Setup- Written and illustrated by Kristopher Tierney

To create the smoke rings a relatively simple experimental setup was used. First, a large, black sheet was hung from the ceiling behind the table on which the experiment was to be conducted. This was to create a plain, dark background to contrast the light smoke rings. Next, a box cutter was used to cut a hole in one of the skinny sides of a cardboard box, which is was then filled with smoke from a smoke machine. Finally, the smoke-filled box was placed on the box from the smoke machine to give it sufficient elevation from the table. To generate the smoke rings themselves, we used a stage fog generator and filled the box opening with smoke. The smoke-filled box was simply given a slight, but fairly quick squeeze on both of the largest sides. This was done with sufficient time between tests to assure no residual smoke nor air turbulence from the previous test remained. No external lighting was used other than the natural light of the sun, which was conveniently overcast on the day this image was taken, providing ample diffuse, grey light.

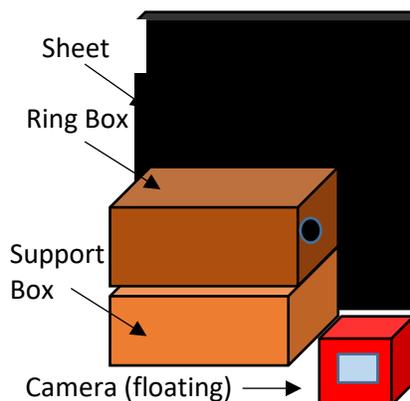


Figure 1: Animated experimental setup (Left), Realistic experimental setup (right)

Filming Technique

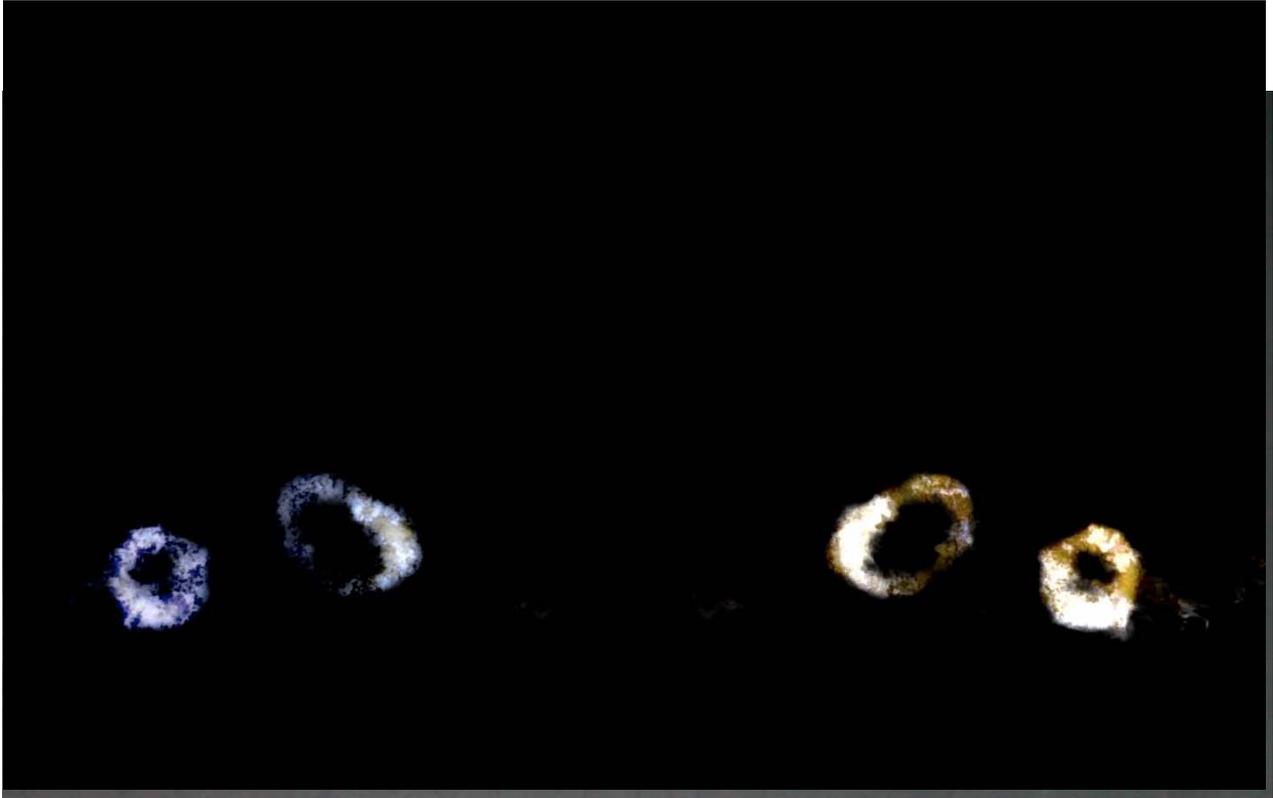
The film was captured using my Canon 5d Mark ii with a 24-105mm telephoto lens. The camera was attached to a tripod which was placed right beside the table we had rest the boxes and fog generator. I captured multiple shots of the rings, some using my lens at 24mm capturing a wide, eight foot field of view and then zooming in to 105mm capturing 0.5 ft field of view. The lens was about two feet away from the rings so it would be able to capture them in focus. When I was shooting at 24mm, I had focused the lens in the path of the test smoke rings. At 105mm, I had simultaneously tracked the smoke rings and pulled focus since there was such a short depth of field. Since we used diffuse, grey light from the overcast day, I had my aperture at f/4 with an ISO 100 and shutter speed of 125 at all times.

When processing the images, I encountered two problems. The first problem was that even with a black background contrasting white smoke, the overall image was grey and was difficult to see all the details of the smoke. The other problem was that there were hot pixels on my camera sensor which I was not aware of before shooting. In order to resolve these two issues, I had overlaid a photograph of my dad's canvas using Final Cut X which increased the contrast of the image and made the negative space completely black and the rings themselves have a beautiful blue and gold texture. I was really pleased with the result, despite losing information of the flow, like the light trails of smoke left behind from some of the rings.

The next editing technique I used was a mirror effect, creating a mesmerizing relationship among the rings. This was a filter in Final Cut X and the video files were moved on the X and Y axis to relate to each other in an interesting way without colliding.

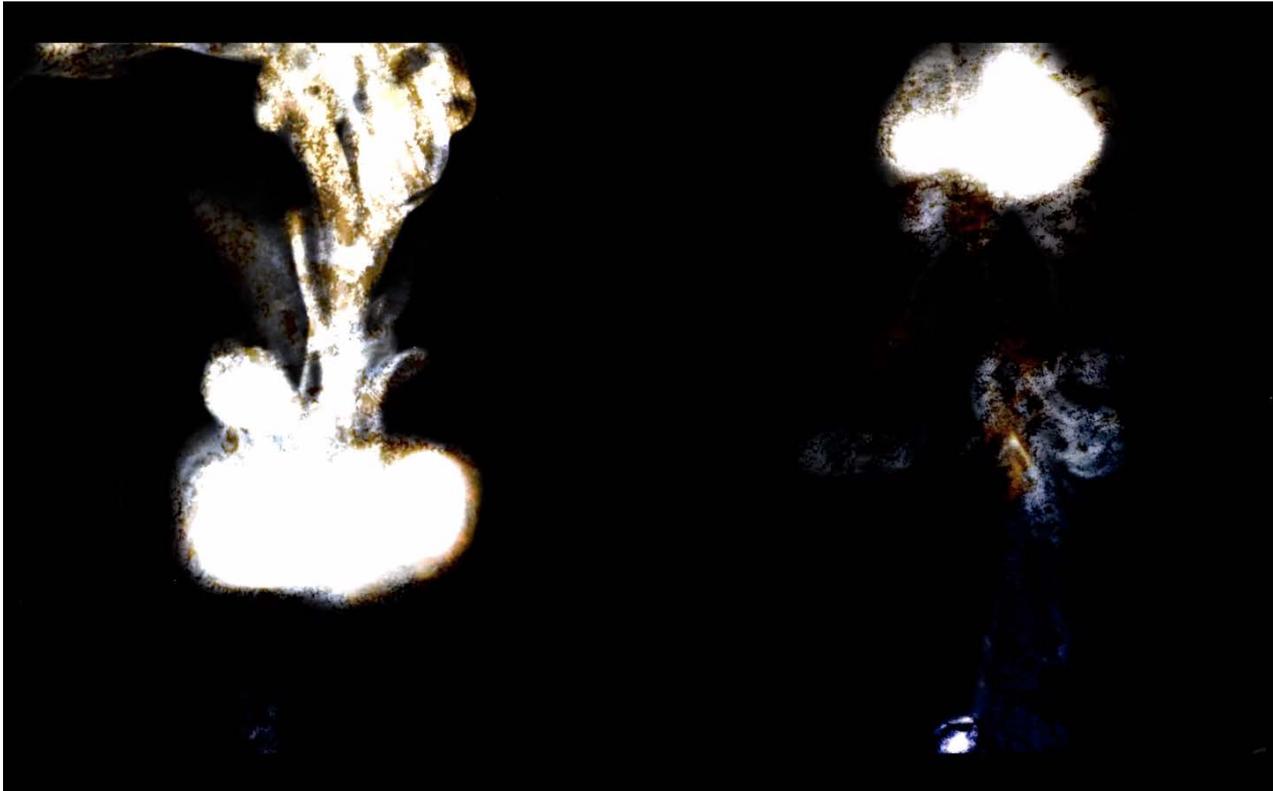
Finally I used two clips in the same shot that looked similar to each other, and then flipped one vertically so one plume of smoke went up and then another went down. I liked the effect so then in a similar way I took three of the widest shots and tacked them on top of each other and had the bottom play first, then the middle shot play slightly after, and finally the top shot play last creating a racing sensation.

I had my friend Michael McNamara compose music for another film project I am working on and was very surprised when I played it to my two minute edit and the audio/visual components "flowed", so decided to use the song with this project.



Original image with hot pixels outlined (Above) and processed image (Below)

Mirror filter applied to shot, contrasting colors (Above)



Two clips in one shot, one flipped (Below)

Conclusion

I really like the final video I created. I think my dad's canvas adds a lot of excitement to the image and makes the smoke rings very dynamic. The video captures the basic movements of the rings, which I think is most important, but does not capture the lighter trails of smoke that follows the rings. I had a wonderful time working with my group and thought our first project was successful. We were able to capture smoke rings as planned. In the future I would like to capture the rings with a light source shooting towards camera and hitting the rings, creating a deeper contrast between the smoke and the backdrop. If this could be achieved, I would shoot without the canvas overlaid on the smoke rings. I would also like to create smoke rings underwater as originally planned in a future project.