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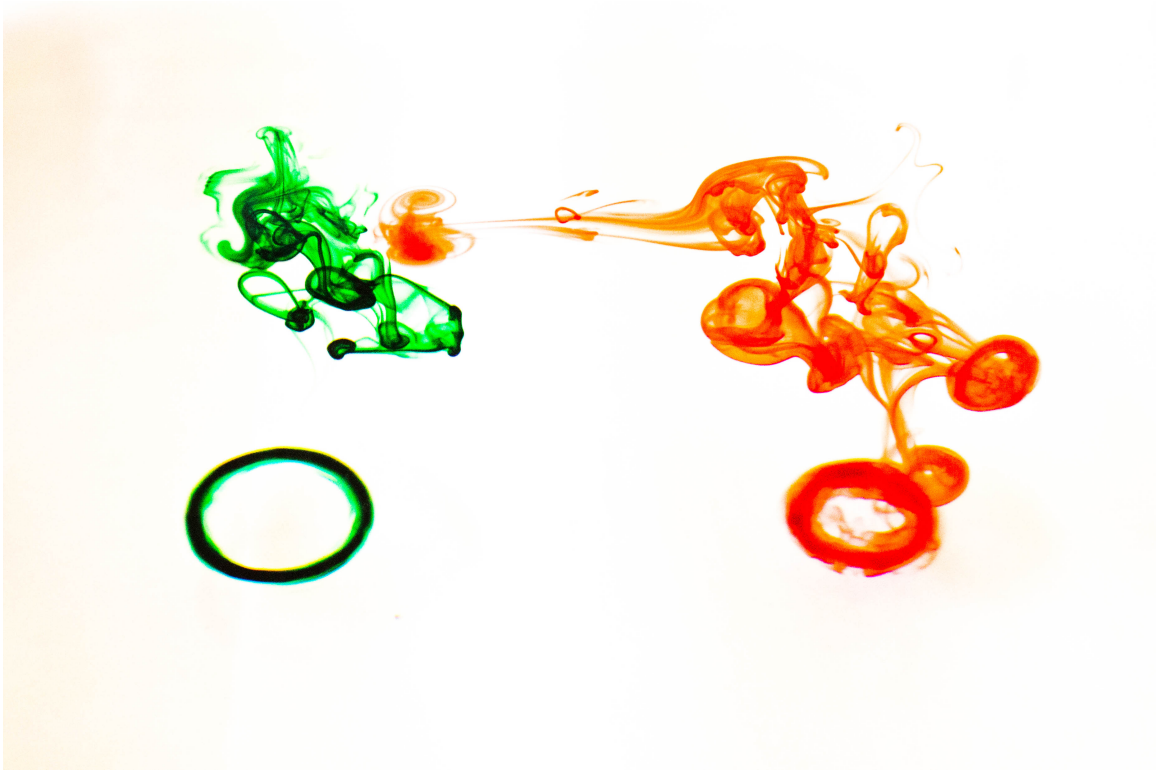
Flow Visualization 2015
Get Wet



Introduction

This image was created for the Flow Visualization 2015 course, Get Wet assignment. The image sought to capture the flow phenomenon when a single drop of food coloring is dropped in water. The image clearly depicts the vortex rings that are formed. Two different color drops, both including vortex rings, are depicted side by side. The following report describes in detail the physics behind the vortices formed and how the technical specification of how the image was captured.

Flow Apparatus

Figure 1 depicts the experimental set up used to capture the image. The flow apparatus was simple. A shallow 7x7x2 inch glass dish was filled with water. The dish was set on white paper to create a clean white backdrop (represented by blue lines in Figure 1). The dish was placed in front of a large window, so the main light source was natural light. The camera was on a tripod approximately 6 inches above the dish, pointing down at an angle of about 45 degrees. To capture the image, two food-coloring drops were released into the water at the same time from a height of 1 inch from the water's top.

Figure 1

Flow Phenomenon

Vortex rings were created by dropping a single drop of each color food coloring into water from a short height. In experimentation, it was observed that these vortices were not always formed. In some cases the food coloring would splash upon impact or create a jet out of the water. There are several factors that cause these vortices to form over other outcomes.

The most observable was the height from which the drops fell. The higher the distance the drops fell, the less likely the vortices were to form. As the drops gained velocity, the impact with the water was more turbulent and was more likely to create a splash. If the food coloring was dropped from a short distance, vortex rings formed.

Furthermore, the oscillation of the drop during its fall, and where it is in that oscillation creates different outcomes. If the drop is spherical during impact with the water surface it will create a clean vortex. If it is at some other point in oscillation the vortex will not be as "energetic". [1]

Lastly, the Weber number, a non-dimensional parameter, can be used to determine what type of impact will occur. The Weber number is the ratio of the time for the drop to deform because of surface tension to the time for the fall to change the diameter of the drop.

$$We = U\left(\frac{\rho D}{T}\right)^{1/2}$$

Where U is the velocity, D is the diameter, and T is the surface tension. If the Weber number is small the drop will create a vortex ring, and if the Weber number is large the drop will create a jet above the water. In conclusion, we can assume that since very clear and "energetic" vortex rings were created, the drop was dropped from an appropriate low height; it was spherical when it impacted the water; and it has a small Weber number. [1]

Photographic Technique

The water that was used was room temperature. The food coloring used was purchased from Target. Multiple colors can be purchased in an assorted pack made by McCormick. No artificial lights were used to create the picture, only natural light in a room with a large window.

Below outlines the photographic specifications that were used to create this image.

Camera	Canon Rebel t5i
Lens	18-55mm f/3.5-2.8
Aperture	f/5.0
Shutter Speed	1/125
ISO	1600
RAW image size	5184 x 3456
Final Edit image size	3711 x 2474

The shutter speed must be fast enough to freeze the image. Therefore, I made the ISO higher, so I could use a faster shutter speed. I used a tripod, and the camera was set to a self-timer that took ten consecutive photos. Therefore, I could place the drops myself and the camera would capture several images.

Below, figure 2 shows the raw image, and figure 3 shows the final edited image.

Figure 2

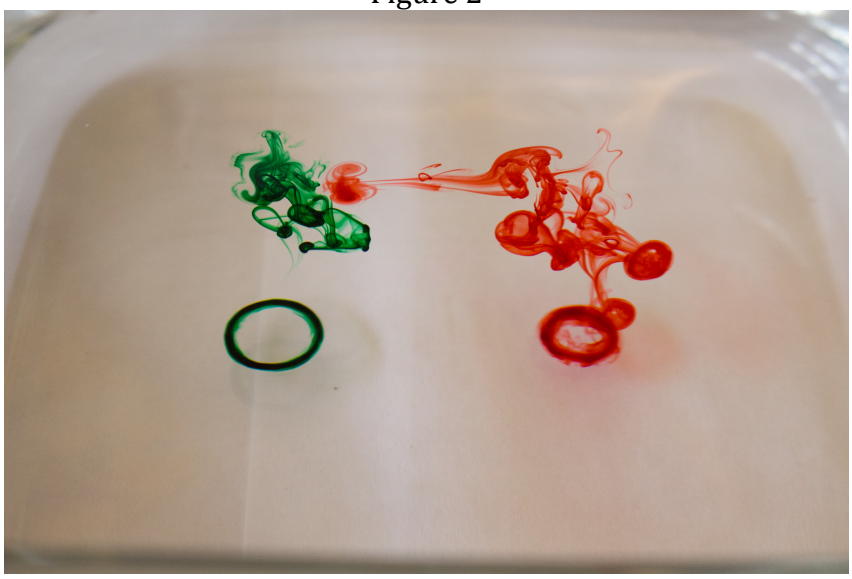
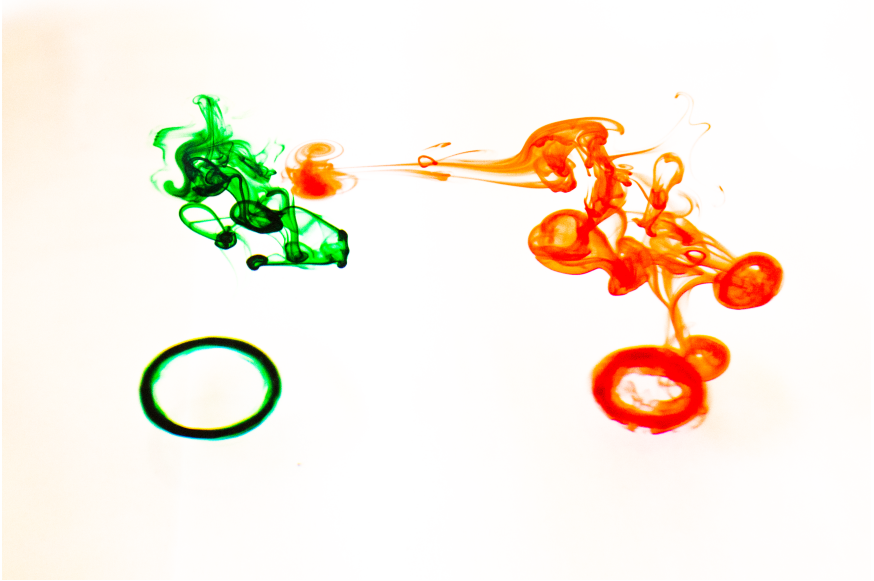


Figure 3



I used Lightroom to edit the image. Initially, I cropped the picture to make it tighter around the subject. Then I adjusted the background, so it is uniformly white using the “whites” bar. Lastly, I adjusted the contrast a little bit. I pulled the contrast up a little bit to make the food coloring more detailed.

Conclusion

When I set out to create this image, this is not the outcome that I expected. I was expecting to see turbulent flow and the umbrella phenomenon when the food coloring was dropped in water, not the formation of vortices. It was a pleasant surprise. Overall, I think I was able to capture the flow vividly and accurately. The colors are vivid and vortex rings in focus. Going forward, I think it would be interesting to create a video of the vortex rings forming. It would be beautiful and educational to have a good, slow motion perspective of how they are formed.

References

[1] Hsiao, M, S. Lichter, and L.G. Quintero. 1988. "The Critical Weber Number for Vortex and Jet Formation for Drops Impinging on a Liquid Pool." *PHYSICS OF FLUIDS* 31(12): 3560–62.