Flow Vis #1: Turbulent Water Coin Splash

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MCEN 4151

Professor Hertzberg

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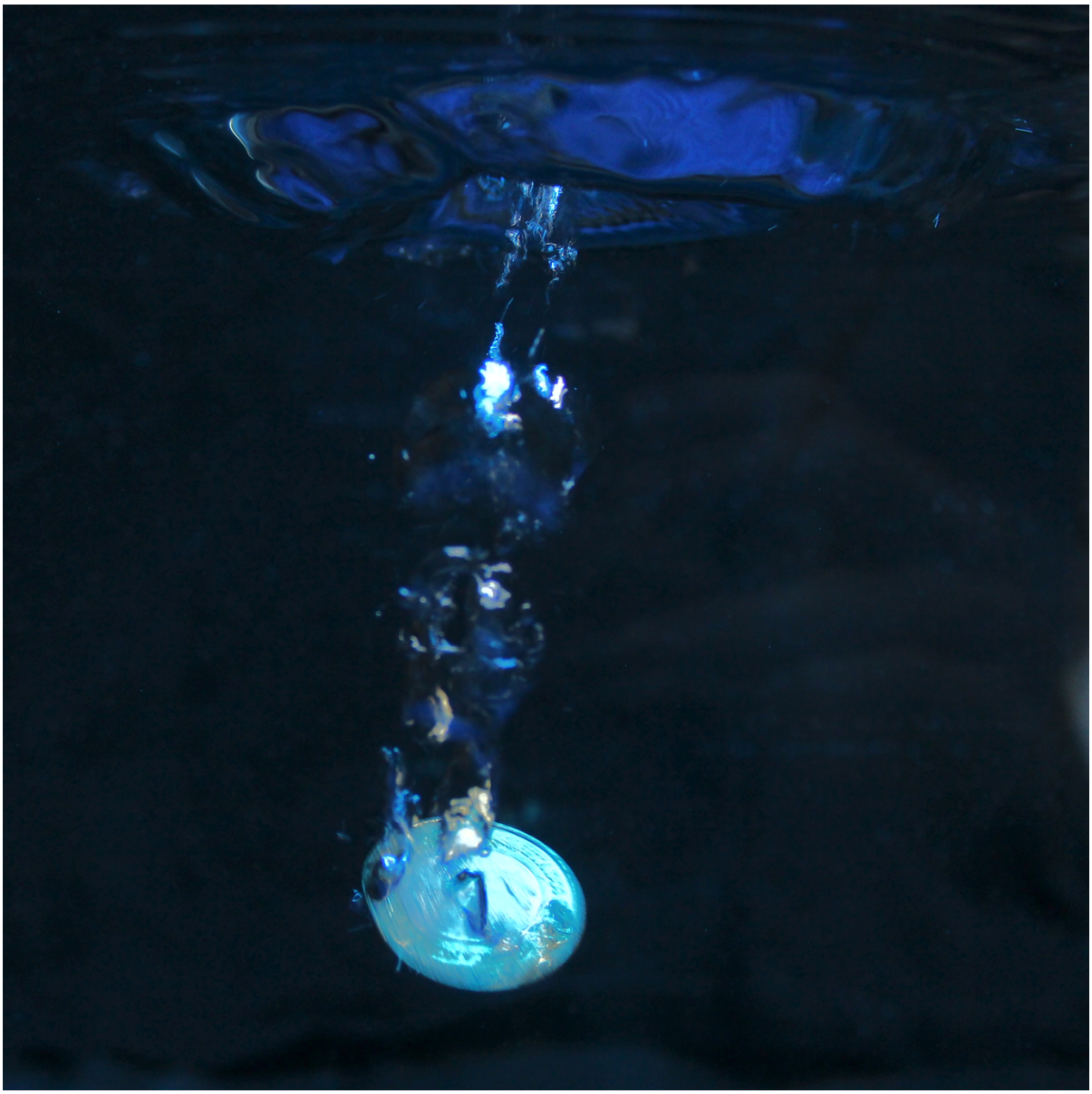

Introduction and Background

The purpose of this photo is for the "Flow Vis 1" assignment which was assigned by Professor Jean Hertzberg for the course Flow Visualization at the University of Colorado at Boulder. The objective of this assignment was to capture a visualization the physics behind the reaction of water in a fish tank from a coin that has been dropped into the water in a way that is aesthetically pleasing. I attempted to capture the turbulent water reaction from a coin dropping from above a fish tank in a way that showed the aesthetics of the water splash in addition to the flow phenomenon.

Team

This assignment was completed with the following team members:

1.) Bryce Dickson
2.) Tobin Price
3.) William Watkins
4.) John Whiteman
5.) ***Procedure***

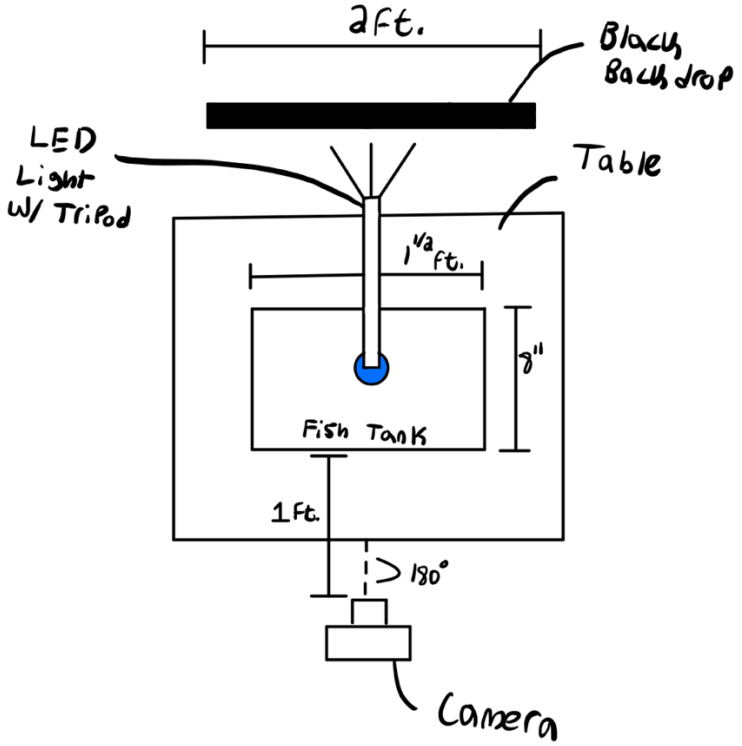

Figure 1: *Illustration of experimental setup*

The experiment began with a fish tank filled completely with tap water placed on a wooden table (refer to Figure 1. Above for the experimental setup and dimensions). A black backdrop cloth was placed behind the fish tank and a blue LED light was held overhead. The black backdrop was stationed and held behind the fish tank using a table approximately 6" behind the fish tank. A small blue rag was placed at the bottom of the fish tank filled with water to ensure that the peso did not damage the fish tank during the drop. A blue light cover was attached to the LED light and the LED light was then attached to a tripod. The tripod was then suspended directly above the fish tank to allow for ample lighting with the LED light being approximately 4" above the surface of the water. The Rebel T7 Camera was attached to a tripod and put directly in front of the fish tank facing the face of the fish tank with the longest side. The Camera was placed approximately 1 ft. in front of the fish tank with the camera lens being orthogonal to the long face of the fish tank. The coin was held in the center of the fish tank (equal length away from each face to its congruent side) approximately 2" from the surface of the water before the experiment began.

To begin the experiment, we had to ensure that there was no natural lighting and our team decided to use Tobin's garage which had no natural light once the door was shut. One team member held the coin above the water and dropped it while I took a photo. The coin was approximately .022 m. in diameter. The photo was taken on the count of 3 in the exact moment that the coin was dropped in order to ensure that the coin falling through the water was able to be captured. At approximately the same time the coin was dropped, the photo was taken. Upon the first few initial tries, it was obvious that the photo burst had to be taken at the approximate moment that the coin was dropped to allow for the time necessary to capture the coin falling through the water. As the coin fell through the water on to the rag, a splash occurred above the original surface of the water. In addition to this, turbulent flow of the water can be seen behind the coin as well as air bubbles.

Materials

Table 1: *Required materials for the assignment*

Required Material	*Description*
2x LED Light with Blue Cover	Two white LED lights with a blue film covering the lights.
2x LED Light Tripods	Two Tripods used to hold each individual LED Light
Fish Tank	One rectangular fish tank of arbitrary dimensions
Camera	Cannon Rebel T7 DSLR Camera
Camera Tripod	Camera Tripod for Cannon Rebel T7 (any model with appropriate dimensions will suffice)
Mexican Peso	One Mexican Peso Coin
Dry Rag	Any Rag that can be completely submerged in water
Tap Water	Any water will suffice (Tap, Bottled, etc.)

The Physics behind the Phenomenon

The coin being dropped into water causes a small jet of fluid shooting out of the surface of the water. As the coin falls into the water quickly causing a cylinder of air in the water, the pressure from the water on the sides of the cylinder causes this air pocket to collapse. This causes a jet of water to shoot straight up from the surface. As the cavity collapses, the diameter of the cylinder gets smaller but the volume of water entering the cavity remains constant. Therefore, the water has to increase in speed due to the lessening space. Ultimately, the water has nowhere else to go but up (reference #6). Although this seems simple, photographing a coin as it falls in water while still being able to have a decent image of the print on the side of the coin is very challenging. Upon calculating the Reynold's number of the coin during the flow through the water (reference Eqn. 1 below), it can be shown that the coin flowing through water was extremely turbulent from the Reynolds number of 323157 calculated (reference #2 and reference #5). Where p is the density of water, u is the speed of the coin in the water, L is the diameter of the coin, and μ is the dynamic viscosity of water. The coin has a diameter of .022 m, the density of water is 1000 kilogram/ m^3 (reference #4), the dynamic viscosity of water is .0010016 N s/ m^2 at 20 degrees Celsius (reference #4) and the speed of the coin was calculated to be 14.715 m/s from the acceleration of gravity multiplied by the time elapsed from the drop (reference #3) which was approximately 1.5 seconds (reference Eqn. 2 below). Where V0 is the original speed of the coin (which is zero because the coin is stationary initially), g is the acceleration of gravity of 9.81 m/s^2, and t is the time in seconds elapsed of the coin since the drop to the moment the photo is taken (approximately 1.5 seconds).

$$Re = \frac{puL}{\mu} \qquad \text{Eqn. 1}$$

$$V = V0 + g*t \qquad \text{Eqn. 2}$$

Photography Technique

The camera used in this experiment was a Cannon EOS Rebel T7 DSLR camera with an 18-55mm lens because it had the best resolution (refer to Table 2. below for camera specifications during experiment). The Camera was stabilized on a tripod perfectly horizontal at a distance of 1 ft away from the fish tank. The lighting used was a singular blue LED light placed directly above the fish tank (approximately 4" above the fish tank). The original photo had a width of 6000 pixels and a height of 4000 pixels while the edited photo was 1300 pixels in width and 900 pixels in height. The original photos exposure width was 2975 pixels in width and 2969 pixels in height while the edited photo's exposure was 2365 pixels in width and 2024 pixels in height. I used the Camera's RAW setting that develops photos in CR2 file. I transferred these photos into PNG using the software Irfanview. I found a YouTube video (reference #1) which gave me a tutorial for how to download this software. This tutorial helped a lot. I used DarkTable to do the photo editing because of its substantial editing features. I edited the photo by adjusting the "rgb" curve

and cropping the photo to emphasize the coin flow through the water which made the photo much more aesthetically pleasing.

Table 2: *Camera Specifications for Cannon Rebel T7 used during Experiment*

Specification	*Description*
Aperture	f/4.0
Exposure	1/100
Shutter Speed	1/200
ISO	400
Focal Length	25mm
Focus Distance	0.44 mm
Priority	Shutter Priority

Conclusion

The objective of this assignment was to capture an aesthetically pleasing visualization of the flow phenomenon that is caused by a coin falling vertically into water. My team and I were able to depict the flow phenomenon behind a Mexican Peso splashing into water vertically causing turbulent air bubbles to form in a steam following the coin. The photo shows in intricate detail the side of the coin falling with a turbulent air flow as the water is ejected vertically upward above in response to the coin. In addition to depicting this phenomenon, the photo was very aesthetically pleasing. For this experiment in the future, a camera with a higher shutter speed would be advantageous as well as having a more ample blue lighting which would allow for a clearer photo. In addition to this, I would want to photograph the coin splash from two angles at once in order to demonstrate the response from two different perspectives. Finally, I would want to learn how to predict the trajectory of the coin better because this has proven very difficult.

Appendix:

1.) "How to Convert RAW Canon CR2 Pictures to JPG PNG or TIF". YouTube. https://www.youtube.com/watch?v=D6viyxBWbnA . Accessed on 09/10/22.
2.) "The Differences between Laminar vs. Turbulent Flow." Resources.system-Analysis.cadence.com, resources.system-analysis.cadence.com/blog/msa2022-the-differences-between-laminar-vs-turbulent-flow.
3.) Communications, Grainger Engineering Office of Marketing and. "Equations: The Speed of a Falling Object | Physics van | UIUC." Van.physics.illinois.edu, van.physics.illinois.edu/ask/listing/115. Accessed 24 Sept. 2022.
4.) Engineering ToolBox. "Water - Dynamic and Kinematic Viscosity." Engineeringtoolbox.com, 2019, www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html.
5.) "Motion of an Object in a Viscous Fluid | Physics." Courses.lumenlearning.com, courses.lumenlearning.com/suny-physics/chapter/12-6-motion-of-an-object-in-a-viscous-fluid/. Accessed 24 Sept. 2022.

6.) Minkel, J. R. “Why Dropping a Stone Makes a Jet.” Physics, vol. 23, 23 Jan. 2009, physics.aps.org/story/v23/st3. Accessed 24 Sept. 2022.

Original Image: