Water Droplet Splash

Image-Video 3

MCEN 5151: Flow Visualization

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Introduction

The report will discuss the flow phenomenon, experimental setup, photographic technique, and conclusions about the flow image. This report is for Image-Video 3 assignment in MCEN 5151 Flow Visualization, and the purpose is to allow students to explore and capture a fluid flow phenomenon. The image needs to be appealing and interesting, while being able to explain the phenomenon with physics. The intent for this photo is to visualize a water droplet splashing on colored water. The motivation comes from my previous observations of water droplets bouncing off surfaces.

Flow Phenomena

We can examine the droplet with momentum, surface tension, and viscosity. The momentum tries to force the drop to spread out due to the mass of the fluid and the impact speed [1]. However, the surface tension of the water tries to pull it back together [1]. An instability occurs when the edge of the drop lifts off [1]. As the water droplet falls, it traps air between the drop and the surface [1]. This air compresses to a thickness of just a few nanometers and pushes the drop outward [1]. This creates a lift off in the form of a splash. It was found that viscosity also plays an impact in the splash [1]. When the droplet spreads out, the edges become shaped like a wedge [1]. The cusp of the wedge moves faster than the top, and the fluid runs out along the surface [1].

I want to use Bernoulli's equation to calculate the impact speed of the droplet.

$$\mathrm{P}_1 + \frac{1}{2}\rho \mathrm{v}_1^2 + \rho \mathrm{g} \mathrm{h}_1 = \mathrm{P}_2 + \frac{1}{2}\rho \mathrm{v}_2^2 + \rho \mathrm{g} \mathrm{h}_2 \text{ [2]}$$

Here, P is the pressure, ρ is the density of the fluid, v is the velocity, g is the acceleration of gravity, and h is the height. In this case, P_1 and P_2 are the same because it is both atmospheric pressures. The ρ is also the same because both are water. Since the droplet starts with no speed, v_1 is zero. I am assuming the top of the surface of the water in the mug to be height zero, so h_2 is zero. This simplifies the equation to:

$$\mathrm{g} \mathrm{h}_1 = \frac{1}{2}\mathrm{v}_2^2$$

Now, rearranging to solve for v_2 to get the impact velocity you get:

$$v_2 = \sqrt{2gh_1}$$

I measured the height between the droplet at the top and the surface in which it impacts on to be about 6 inches or 0.1524 meters, so $h_1 = 0.1524\ m$. The acceleration of gravity is $g = 9.81\ m/s^2$. This gives an impact speed of $v_2 = 1.73\ m/s$.

Experimental Setup

The object is to capture a water droplet splashing or bouncing off colored water. The experimental set up is shown in Figure 1. The equipment list includes water, a mug, food dye, DSLR camera, sink and bathroom lighting. The DSLR camera is a Canon PowerShot SX540 HS purchased from Best Buy. The Kroger Food Colors was purchased from King Soopers, and it came in a variety pack. The water, mug, sink, and bathroom lighting were sourced in-house.

The mug needs to be filled with water, and then apply the food color into the water. I used yellow, but any other color is fine. The purpose for coloring the water is to make the water base more visible. Then, more water is added to the mug to fill it up to the rim. The mug is placed in the sink and sits below the faucet. Next, turn the faucet just a little, so that it drips. This will be the water droplet that will splash on the colored water. Finally, adjust the exposure settings in the camera, and take numerous pictures to get the best one. This is the hard part because the droplet falls very quickly. I tried to get the highest shutter speed I can get, while maintaining good lighting. In addition, the camera cannot sit too close to the splash because it will get wet. The splash also created a mess in the sink, but cleanup was easy.

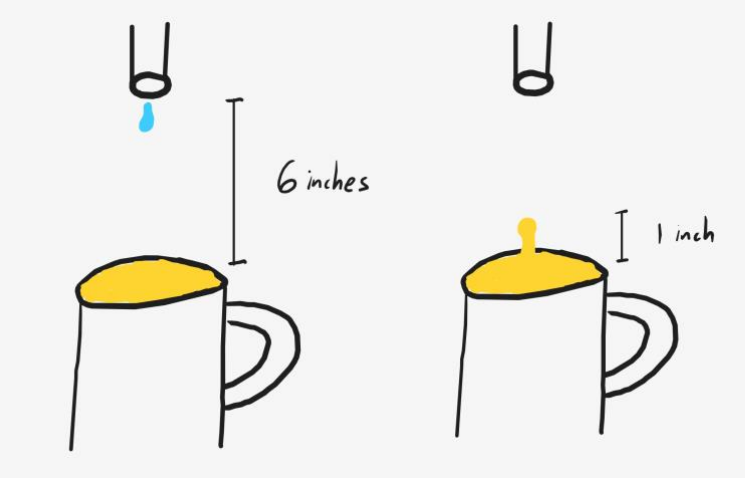

Figure 1. Water Droplet Splash Set Up

Photographic Technique

The distance between the lens of the camera and the splash is about a foot. The reason for this distance is that the lens will get wet if approached closer. The aperture, focus, shutter speed, and ISO were manually adjusted before the experiment to get the best quality image. The bathroom lighting was used as the light source. Unfortunately, it looked a little dim on the camera, so I had to increase the ISO a good amount. As mentioned before, the shutter speed was optimized to take quicker shots. Table 1 shows the camera used and exposure levels.

Camera	Canon PowerShot SX540 HS (DSLR)
Aperture	F5.0
Focal Length	35mm Equivalent
ISO	3200
Shutter Speed	1/200
Height	3888 pixels
Width	5184 pixels
Photo Size	5.51 MB

Table 1. Photo Specifications

The photo was edited on Gimp. The first thing I did was to crop the image. I wanted to focus more on the splash and to center it. I increased the exposure, saturation, and contrast. These all enhanced the visual by adding more color and brightness to the image. As you can see from Figure 2, the edited image has more vibrant colors and brightness, which makes it more appealing. I also adjusted the RGB curve slightly by making some of the dark spots brighter. Even in high ISO setting, the brightness of the image was poor. This shows that my light source was not good, and I should have added a brighter light source. Nonetheless, the edits helped brighten up the image and achieved a more appealing photo.

Figure 2. Before and after photo edit on Gimp

Conclusion

The image shows a water droplet splashing on colored water. This image was harder to capture than I initially thought due to the quickness of the splash. I spent a lot of time taking quick photos to capture this bounce. My original idea or inspiration was to capture a spherical droplet coming out from the splash. However, I realized that my camera may not be good enough to capture it, and I probably needed more height (faucet to colored water). I found that the splash of water is more complex than it seems in terms of calculations and modeling it with math. I used Bernoulli's equation and simplified it to solve for the impact velocity or the velocity at which the droplet hits the surface of the water. The impact speed resulted in $v_2 = 1.73\frac{m}{s}$. I was surprised about the height that the water splashed up to. From just about 6 inches, it was able to bounce about 1 inch on water.

A weakness of the image is the natural lighting. If I had better lighting to start with, the focus and quality of the photo would be better. It would also allow me to set the shutter speed at a higher setting to capture the photos faster without sacrificing brightness. Overall, I am happy about the image, and I fulfilled my intent to capture a water droplet splash. I could further develop this idea by having a different liquid for the base and see how the characteristic of different liquid affects the water droplet splash.

Reference

[1]: Chris Lee. “The Physics of Water Drops and Lift-Off.” *Ars Technica*, 13 Apr. 2014, https://arstechnica.com/science/2014/04/the-physics-of-water-drops-and-lift-off/.

[2]: “Bernoulli Equation.” *Pressure*, http://hyperphysics.phy-astr.gsu.edu/hbase/pber.html.