Seth Dry – Get Wet Report

MCEN 5151 September 23rd, 2025

Figure 1 – Final Image

I created the image show in figure 1 above as my submission for the “Get Wet” assignment for the flow visualization course at CU Boulder. My intent for this image was to capture a flow phenomenon known as a Worthington jet, which occurs just after a droplet of a fluid impacts a fluid surface, and we can quite clearly see two of these Worthington jets in the final image. Artistically, my intent was first and foremost to capture the phenomena in a way that was clearly distinguishable to the final viewer, but also compositionally and aesthetically compelling. I think my image was successful on both counts. The final image captures two Worthington jets that are clearly visible and distinguishable, as well I am very pleased with the image’s composition and aesthetic. The presence of two jets gives an aesthetically pleasing sense of symmetry and adds and sense of contrast.

The Worthington jet is a fluid phenomenon that occurs as a result of the impact of a droplet of liquid onto a liquid surface. “When such a [drop] hits a pool of water, the drop forms a crater or cavity around the place of impact. When subsequently the water flows back and the cavity collapses, a small water jet is propelled up into the air” (Van Rijn 2021). This jetting phenomena is however not the only behavior that can occur when a drop impacts a surface. As discussed in (Rein 2006) an impinging droplet may broadly either form a jet, or coalesce with the fluid, with either category having a few different behaviors depending on certain factors. Rein also proposes that the behavior of the impinging droplet is primarily reliant on the dimensionless Weber number, and that coalescence is dominant for lower Weber numbers. As the Weber number increases beyond about 75, jetting is expected. The exact form of the jet changes as the

Weber number further increases. The Weber number itself is a ratio between the kinetic energy of the impinging droplet to the surface energy of the impacted surface; it can be expressed as:

$$\mathrm{We} = \frac{\rho \mathrm{v}^2 \mathrm{l}}{\sigma}$$

Where ρ is the density of the fluid, v is the velocity of the impacting droplet, l is the diameter of the droplet and σ is the surface tension of the impacted fluid (Wikipedia 2024). Using this definition, we can calculate an approximate Weber number for the jets shown in my image. We will take the density of water to be 997 kg/m^3. I don't have a great way of measuring the velocity of the droplet so we will take it to be ½ of the terminal velocity of a raindrop of similar size as calculated in (Serio 2019), giving us a value of 4 m/s. Using pixel measurements along with the know FOV of the image, we can determine a droplet size of about .12 inches or about 3mm. We can take the surface tension of water to be .0712 N/m (The Engineering Toolbox 2004). Plugging these in we get

$$\mathrm{We} = \frac{(997)(16)(.003)}{(.0712)} = 672.13$$

Looking again to (Rein 2006) this puts us well into the jet formation regime and predicts that we will have a thick jet, along with crown formation on impact. We can see quite clearly that we do have a thick jet, and in other photos we can see a crown does form upon droplet impact.

To capture the Worthington jet phenomena, I used a Tupperware full of water to contain and create a liquid surface to be impacted and then used a syringe to create a controllable stream of water droplets to impact the surface. I then placed my camera about 4 feet away from the front edge of the Tupperware. To create the Worthington jets, the syringe was pushed with increasing force until there was a continuous stream of separated water droplets of approximately equal size falling from the syringe. The syringe was held at about 1 foot above the water's surface. Using a continuous stream of droplets allowed for the formation of many Worthington jets in succession on the water's surface.

Figure 2 – Flow Apparatus and Camera Setup

As these drops hit the waters surface, I used the cameras continuous release mode to take as many pictures as I could while the stream of droplets were falling. I was somewhat relying on luck to capture the phenomena, but out of the 400 or so pictures I took, about 200 had the Worthington jet visible in some capacity.

The visualization of this flow relies primarily on the differing indices of refraction and opacity between air and water that allows for the camera to capture the forms of the resulting Worthington jets in a way the human eye can distinguish in the image. I found that having appropriate lighting behind the jets was important to have clearly visible jets. In attempts where the camera was at a different angle or had more light coming from behind the camera, I found that the border between the jet and the liquid surface was more difficult to distinguish in the final image. To create enough backlighting, I used a white backdrop, which did a good job of reflecting sunlight to backlight the image and create a distinguishable border. The image was lit by direct sunlight outside, on a clear day.

This image was taken using a Nikon model D3200 DSLR camera using a 200mm lens. The field of view in the original image is about 7 inches, and the camera is about 4 feet away from the flow phenomena. To capture this image, I was mainly concerned with having a fast enough shutter speed to effectively freeze the Worthington jet with no motion blur, or to have no apparent movement of the flow during the timescale of the photo, which I achieved. To achieve this, I was shooting in shutter speed priority mode with a shutter speed of $1/800^{th}$ of a second. To achieve proper expose the aperture was set by the camera at f/5.6, which limited the depth of field, but not enough to affect the visualization I was trying to achieve. I shot using an ISO of 400 as I have had great success in the past using this film speed in sunlight. The original image, shown below in figure 3 had a resolution of 6034 x 4012 pixels.

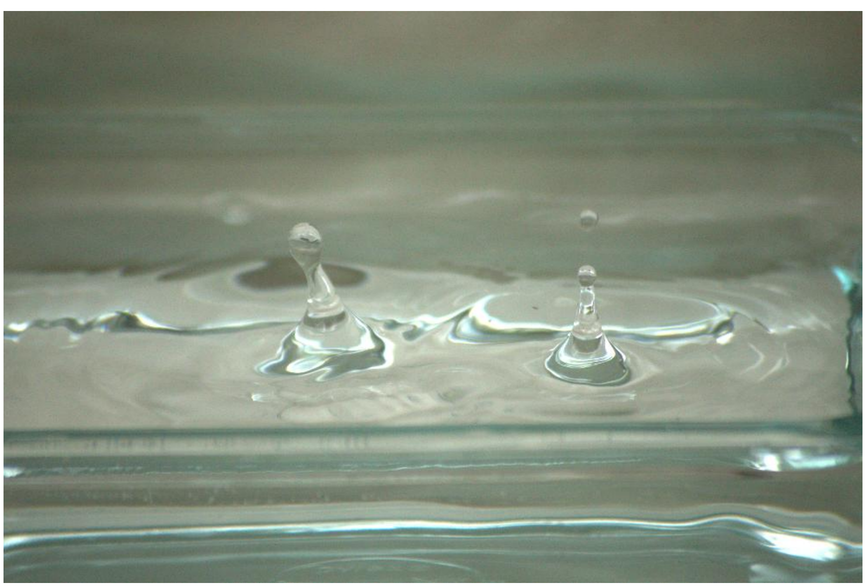

Figure 3 – Unedited Image

The image was processed using Darktable. The first post processing operation was to crop the image to 5581 x 2668 pixels. This crop cut out some of the more distracting elements of the flow apparatus that were still visible in the image. I then used the RGB curve editor in Darktable to drop the intensity of the more intense white colors in the image, while boosting the intensity of the blue tones in the image, giving a more monochromatic and contrasted image.

This image ultimately reveals what I think to be one of the most interesting fluid phenomena. Ever since I first saw a video showing this Worthington jet behavior, I have been interested in this formation. I think it is especially interesting how frequently we can observe these jets, from raindrops hitting a pond, to pouring coffee creamer or mixing drinks, anytime one liquid impacts another, there is a chance for the jet to form, and for us to see it if briefly. I think this image does a good job of capturing that split second of interesting physics that can happen all around us. I am also quite happy as I mentioned before with the aesthetic quality of the image. The exposure and color scheme of the image provide good detail and contrast to highlight the Worthington jet phenomena, and I am especially happy with the symmetric yet opposed composition given by the two jets happening simultaneously.

References

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