Get Wet: Image Report

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The purpose of this image was to begin personal exploration into the world of flow visualization, which is the combination of art and fluid dynamics. The intent of this particular image was to display the physics of water droplets (or Worthington jet) in a visually appealing way. I was unsure of which phase of the droplet process I wanted to capture, so I took many pictures to fully describe what was happening. However, in the end I chose to display the "jet" portion of the phenomenon.

Figure 1: Apparatus to capture water droplet

The apparatus I used to capture this image was very simple (shown in Figure 1). I did not have the necessary materials to fully control the location of the droplet or even the location of the camera (tripod), so much of the picture taking process was based solely on luck. To make the droplet I simply poured water out of a shot glass and into the pot, and took a bunch of pictures hoping to capture something interesting and in focus. It took about 650 pictures to get one that I was satisfied with.

To get a crisp image, the time resolution (shutter speed) had to be pretty quick. The water droplet was dropped from a height of about 1 foot. From this the velocity can be calculated, using the conversation of energy, from potential to kinetic.

$$mgh = \frac{1}{2}mv^2$$

$$v = \sqrt{2gh} = \sqrt{2 * \left(32.2\frac{ft}{s^2}\right) * (1ft)}$$

$$v = 8.02\ ft/s$$

Therefore, it was very important to have quick shutter speed to crisply capture the phenomenon. Different phases of the Worthington Jet will be moving at different velocities, but this simple calculation indicates the order of magnitude. The spatial resolution needs to be fairly small since the phenomenon is probably only about ~1 inch in magnitude. If we approximate “in focus” as an object moving 1/10th of it’s size with the shutter open, this means that the shutter speed should be about:

$$shutter\ speed = \left(\frac{1\ in}{10}\right)\left(\frac{1\ ft}{12\ in}\right)\left(\frac{1\ s}{8.02\ ft}\right) = 1 \times 10^{-3} s$$

Keep in mind that this would be to capture the water droplet as it impacts the water, which is the highest velocity throughout each stage of the phenomenon. Since I had to use a flash for this setup, the shutter speed was actually an order of magnitude higher (1/60 s), but it still captured the droplet clearly.

In terms of the actual physics taking place in a Worthington Jet, it can be quite complicated. In basic terms, the droplet can be considered to demonstrate the principle of the conservation of momentum. However, instead of a purely elastic collision (like 2 rubber balls colliding), much more energy is absorbed. First, the droplet creates a crater upon impact (shown in Figure 2, another picture I captured). Since the water in the pot does not absorb all of the energy from the original droplet, some of the momentum must be reflected back, which is where the jet comes from. The jet does not return to the original height of the droplet because some energy was dissipated, and because there is now more moving fluid involved in the phenomenon.

Figure 2: "Crater" phase of a Worthington Jet

The visualization technique used was not complicated at all. It simply involved a pot of water with a colorful backdrop (so a rainbow-like reflection appeared on the surface of the water) and a large floodlight to lighten the images. The built in camera flash was used as well to make the image more crisp and with an appropriate exposure.

In terms of a photographic technique, a lot of this process was trial-and-error. I personally don’t know that much about photography, so I just had to play with the settings on my camera until I got an image that I liked. The camera that I used is a Canon EOS 20D. The F-number was 5.6, and the focal length was 55. The lens is the standard lens that comes with the camera, EF-S 18-55mm f/3.5-5.6 IS II. The camera was held about 1 foot away from the water droplet. The shutter speed was 1/60 s, with ISO 400. The original image was 3504 X 2336 pixels. Again, I knew that I needed a small field of view and a fast shutter speed, but it was a matter of playing with the settings until it worked well.

Overall, I'm very satisfied with how this image turned out. The original image (Figure 3) was a little bit far away and the colors weren't as vibrant as I wanted, so I cropped and photoshopped the image a little bit to better demonstrate the idea I was trying to capture. The fluid physics are shown fairly well, however it would be neat to see later stages of the Worthington Jet, which I didn't manage to capture fully in focus. I do like how there are bubbles coming up through the center of the jet though, which is a piece of this phenomenon that I haven't seen before. To develop this idea further I could use a more sophisticated setup to better execute water droplets, and perhaps even colliding droplets so that more advanced photos could be taken.

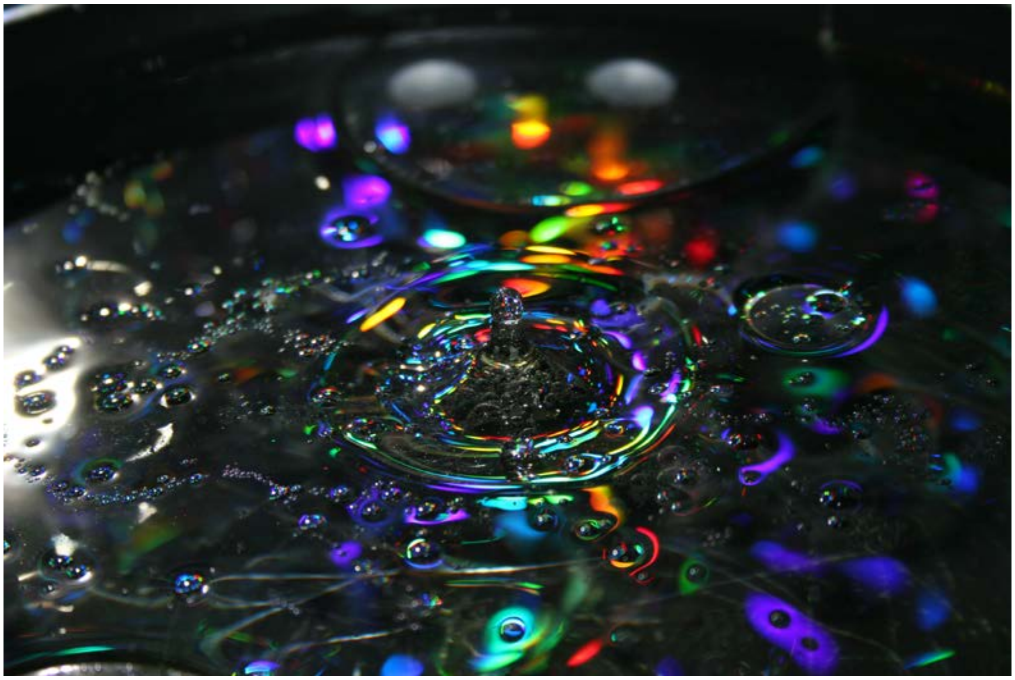

Figure 3: Original image