Get Wet: Image Report

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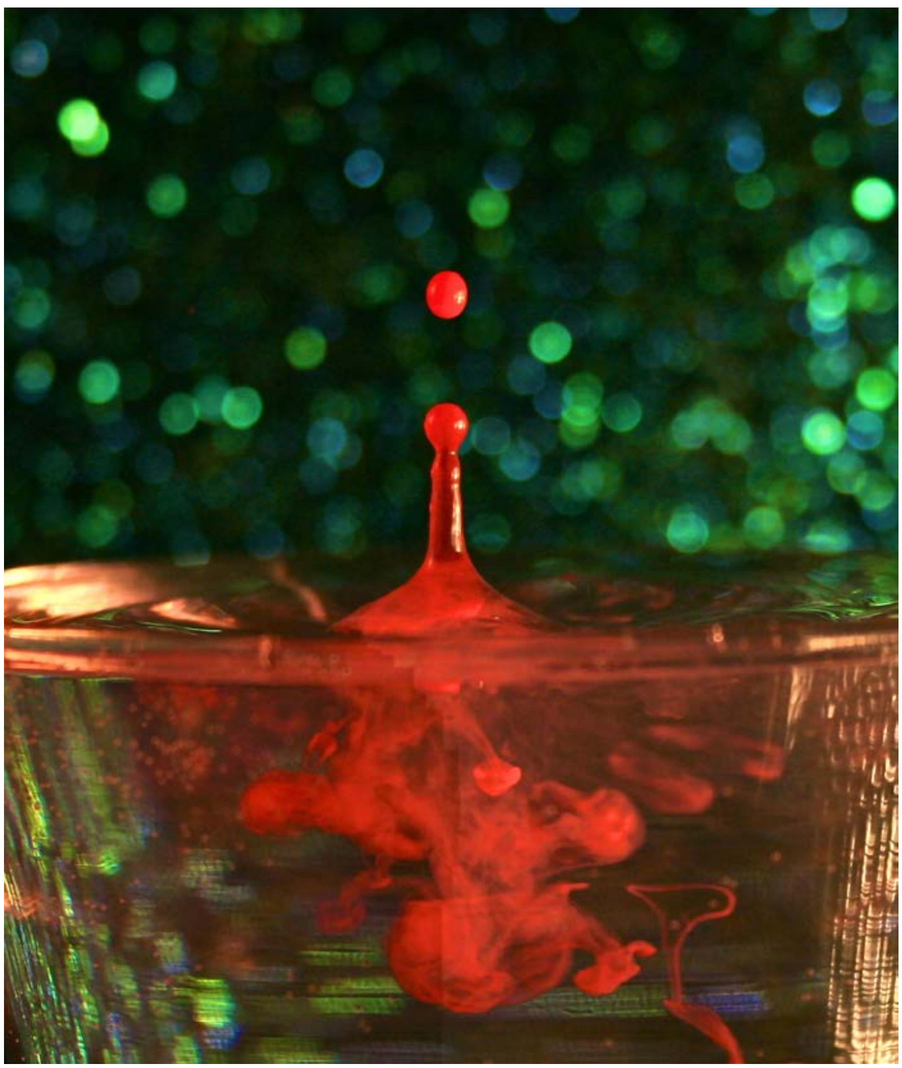

The purpose of this image was to further explore the world of flow visualization, which is the combination of art and fluid dynamics. The intent of this particular image was to display the physics of water droplets (or Worthington jet) in a visually appealing way, also while capturing the dispersion effects below the surface. 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.

The apparatus I used to capture this image was very simple. There was a sparkly blue/green background, with a glass of isopropyl alcohol in front. The camera was on a tripod, and colored milk was dropped into the alcohol. I did not have the necessary materials to fully control the location of the droplet, so much of the picture taking process was based solely on luck. To make the droplet I simply dripped the colored milk with a small medicine dropper, and took a bunch of pictures hoping to capture something interesting and in focus. It took about 800 pictures to get one that I was completely 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 2 foot. From this the velocity can be calculated, using the conversation of energy, from potential to kinetic.

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

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

$$v = 11.35\ ft/s$$

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:

$$shutter\ speed = \left(\frac{1\ in}{10}\right)\left(\frac{1\ ft}{12\ in}\right)\left(\frac{1\ s}{11.35\ ft}\right) = 7 \times 10^{-4}\ s$$

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. With such a fast shutter speed, there had to be a lot of light, and there were multiple high power lamps on the setup. The actual shutter speed used of 1/3200 s ($3 \times 10^{-4}\ s$) was very close to this approximated value.

In terms of the actually 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. Since the alcohol in the glass 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. The dispersion effects below the surface are more related to differences in density rather than momentum. The milk splits up within the alcohol since the density is different, and eventually mixes in with the alcohol. Since the densities are not extremely different, the two fluids do not separate eventually.

The visualization technique used was not complicated at all. It simply involved a glass of isopropyl alcohol with a colorful backdrop and a large floodlight to lighten the images.

In terms of a photographic technique, a lot of this process was trial-and-error. The camera that I used is a Canon EOS 20D. The F-number was 5.6, and the focal length was 46. 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 1/3200 s, with ISO 200. 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. I do like how the image shows both the Worthington Jet, and dispersion below the surface, which I haven't captured in one picture together 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 1: Original Image