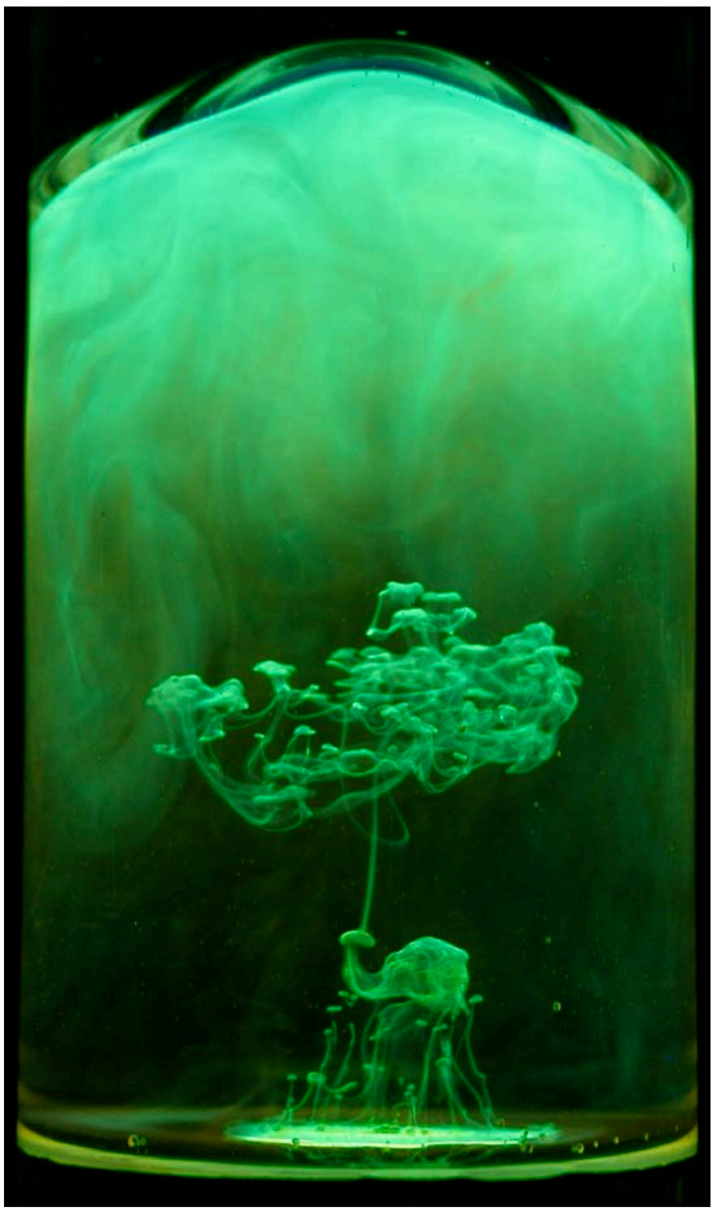
# Team First Image: Report

**Liam Murphy**

**3/12/14**

**MCEN 4151**



The purpose of this image was to begin team-centered exploration into the world of flow visualization. The intent of this image was to capture a phenomenon with bright contrast, demonstrating water droplet instabilities 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 Rayleigh-Taylor instability.

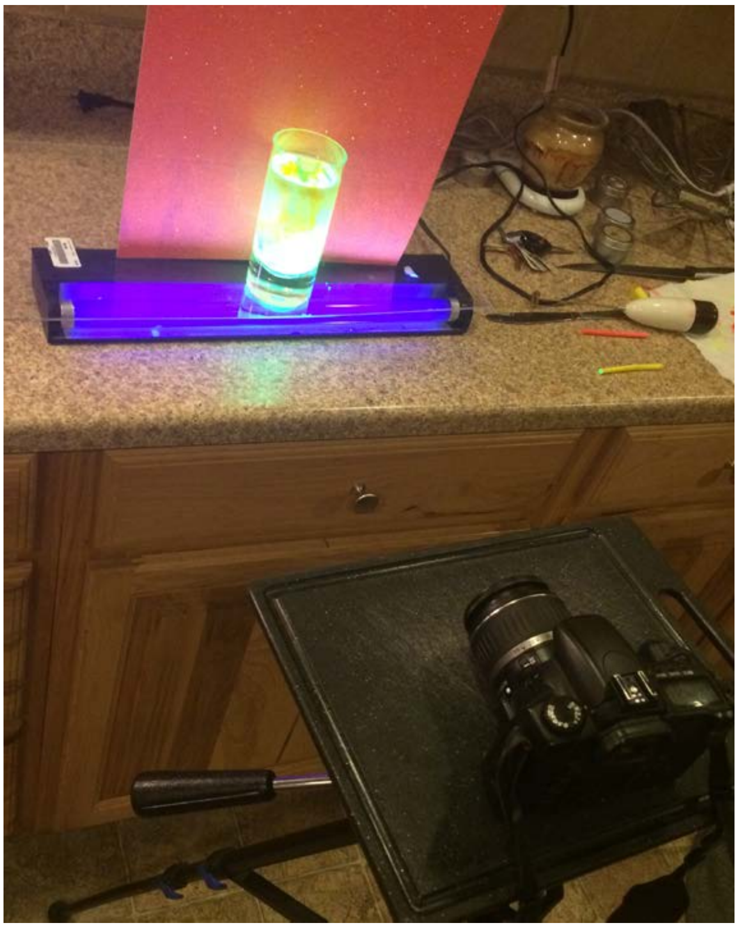


Figure 1: Apparatus for image capture

The apparatus I used to capture this image was very simple (shown in Figure 1). There is a glass with water, sitting on top of a slab of Plexiglas. This is all sitting on top of a black light. There is also a red background to add color variation. To make the droplet I simply dripped ink out of a highlighter tube and taking a bunch of pictures, hoping to get one that I liked. It took about 500 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.

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

$$v = \sqrt{2gh} = \sqrt{2 * \left(32.2\frac{ft}{s^2}\right) * (6\ in)\left(\frac{1\ ft}{12\ in}\right)}$$

$$v = 5.67\ ft/s$$

Therefore, it was very important to have quick shutter speed to crisply capture the phenomenon. This calculation indicates the maximum velocity (right when the ink hits the water), so this is the quickest shutter speed to ensure crisp focus. 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 actually physics taking place in a Rayleigh-Taylor instability, it can be quite complicated. In basic terms, there are shear forces acting on the highlighter ink as it flows through the water. Since there are density differences between the two fluids, they will not immediately mix completely. The center of the "jet" will travel further since it does not have shear force acting directly on it. The edges of the flow will slow down, thus creating a stream effect. This happens numerous times, creating a sort of bag-like object.

The visualization technique was based off of using a black light to make a neat image with bright colors. This same effect could have been captured using simply water and food coloring, but I really liked how the highlighter ink was bright with the black light underneath. However, to capture this phenomenon in focus was a little bit tricky. For the black light to have full effect, the image had to be captured in complete darkness. Therefore, the camera had to be focused with the lights on (automatic focus) and then switched to manual focus so it would not readjust when the image was ready to be taken in the dark. Additionally, the image was flipped for a neat effect.

In terms of a photographic technique, a lot of this process was trial-and-error. A low aperture and a fast shutter speed would ensure an image that was in focus, but a fairly high ISO had to be used to make sure that the image had a high enough exposure. The camera that I used is a Canon EOS 20D. The F-number was 5.6, and the focal length was 43. 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 2 feet away from the ink droplet. The shutter speed was 1/60 s, with ISO 400. The original image was 3,504 X 2,336 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 2) had a lot of black space, so I cropped the image down to just focus on the glass. The only other thing that was altered was the sharpness, to really bright out the phenomenon clearly. The fluid physics are shown fairly well, including different stages of the instability to show a fluid progression through time. To me, the image looks like an elephant head holding an umbrella in its trunk. I especially like this image because it's open to interpretation such as that. To develop this idea further I could use a more sophisticated setup, including more colors, to better capture this phenomenon in an even more stunningly visual way.

**Figure 2: Original Image**