Team First Report

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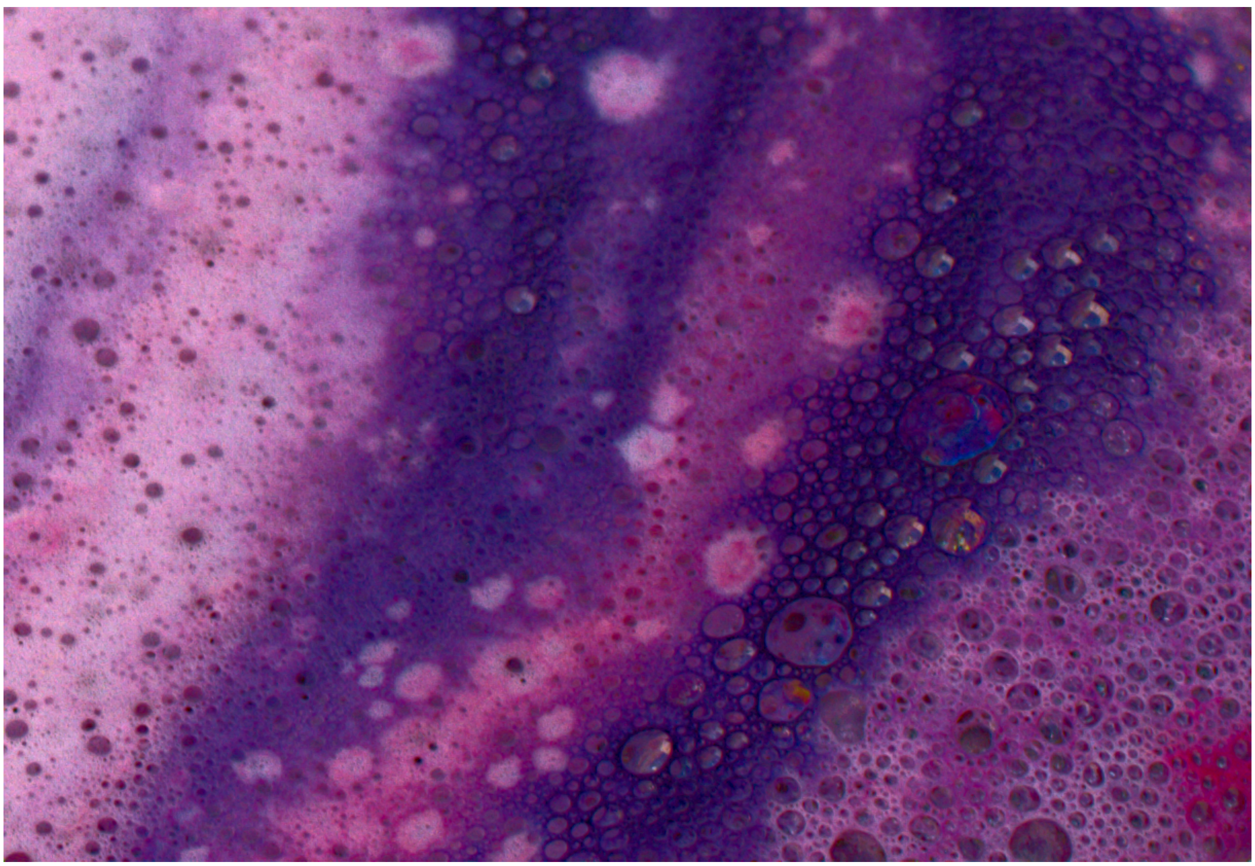

Figure 1. Final Image of the Foamy Aftermath of an Elephant's Toothpaste Reaction

Background

This image was created for the second visualization assignment of the Flow Visualization course: Team First, with the help of Jessica Vo and Adiba Ashrafee. The image is a cropped photo of the foamy pink, purple, and white pool that spilled onto the table after the elephant's toothpaste reaction. The intent of this image was to show the interesting colors and textures that occurred as a result of the experiment. The intended phenomenon to be captured was the large foamy chemical reaction of the elephant's toothpaste experiment. The reaction wasn't as large as we thought it was going to be, so I decided to focus on the patterns created by the foam as it spread over the table. The experiment was set up by Adiba and I, and Jessica poured in the yeast mixture that caused the reaction to occur. All of us brought materials to use, and some were borrowed from the Integrated Teaching and Learning Laboratory (ITLL) at the University of Colorado Boulder. When taking photos of the reaction, Jessica helped hold the ruler over the subject to use as a means of focusing and size reference.

Fluid Physics

The flow phenomena can be described as upward buoyancy-driven, and is caused by the flow of oxygen bubbles from the reaction creating an upward flow of foam, which is stabilized by the surface tension created by the soap. The *elephant's toothpaste* reaction, as described in the Children's Museum of Sonoma County experiment, involves the rapid decomposition of hydrogen peroxide into water and oxygen gas. This is sped up by a catalyst, typically yeast, which contains the enzyme *catalase*. This enzyme breaks down hydrogen peroxide (H_2O_2) into water (H_2O) and oxygen (O_2) at a much faster rate than normal. The oxygen gas that is produced forms bubbles, which get trapped in soap added to the mixture, creating the large foam eruption that looks like toothpaste squeezing out of a tube. The setup for this experiment can be seen in the drawing in *Figure 3*.

- The diameter of the bottle's body is Dbody=2.37" (=0.0602m) and the diameter of the opening is Dmouth=0.875" (=0.0222m). The velocity of the foam will increase at the opening because the bottle opening is smaller than the body and the principle of conservation of mass. Due to this, when calculating for the reynolds number the velocity of the foam exiting the bottle can be assumed to be V=0.5m/s. The viscosity and density of the 3% hydrogen peroxide and dishsoap solution will be close to that of water because the peroxide is mostly water and dish soap doesn't dramatically change the viscosity. Therefore the viscosity can be assumed to be μ≈0.001 Pa · s (close to water) ans the density can be assumed to be ρ≈1000 kg/m^3 (close to water). The Reynolds number can be calculated as:

$$Re = \frac{\rho VD}{\mu} = \frac{(1000\frac{kg}{m^3})(0.5\frac{m}{s})(0.0222m)}{0.001\ Pa\bullet s} = 11100$$

This Reynolds number indicates turbulent flow. The smaller diameter of the bottle opening compared to the body increases the velocity of the foam, and as a result the Reynolds number is larger. This reinforces the fact that the flow will be turbulent as it exits the bottle.

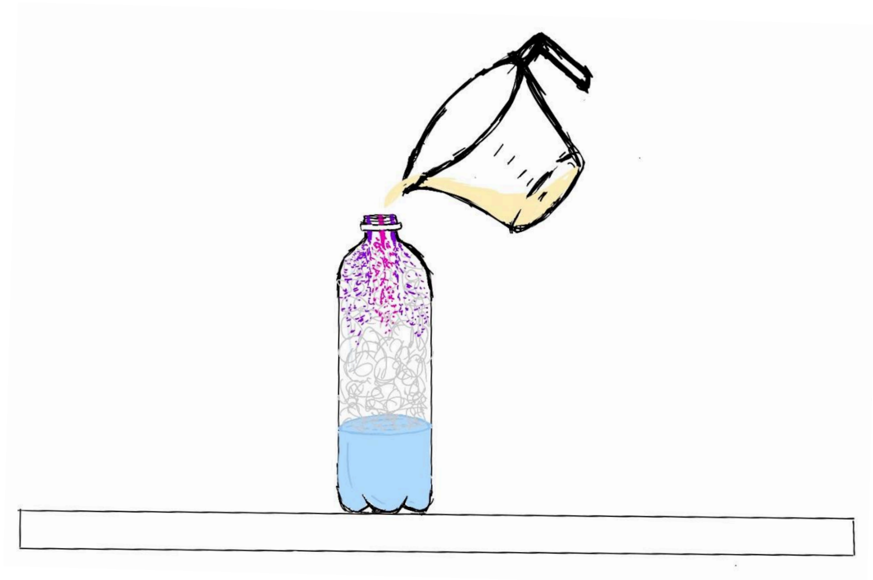

Figure 2. Flow Apparatus

Visualization Technique

The visualization techniques used to capture the final image (*Figure 1*) are easy to replicate. Using the materials shown in *Figure 4*, combine ½ cup of 3% hydrogen peroxide and a large squirt of dish soap in a tall, skinny, cylindrical bottle with a small opening (we used an empty, clean, sparkling ICE bottle). After we mixed the two to combine by shaking the bottle, we taped the bottle to the table using masking tape and added drops of food coloring in an alternating pattern at the opening of the bottle so it dripped down along the sides/in the foam from shaking. We allowed the mixture to sit for roughly a minute while we mixed around 3 tablespoons of warm tap water, with around a tablespoon of yeast. When it was time to perform the experiment, Jessica poured the yeast mixture into the opening of the bottle and stepped back as the reaction began. The experiment was conducted outside with a bucket of water nearby, and all the experimenters were wearing safety goggles. As this experiment was conducted outside during the day, we used natural lighting.

Figure 3. Materials used for the experiment

Photographic Technique

The image was taken on a Canon EOS 2000D (also known as the Canon EOS Rebel T7) at a distance of roughly 6” above the flow. The lens used was a Canon zoom lens with an 18-55mm focal length, 1:3.5-5.6 aperture, and a thread diameter of 58mm. The original picture (*Figure 4*) was 6000 x 4000 pixels and was cropped to 1214×831 pixels (*Figure 1*) which focused on the striations of the dye in the flow and the texture as a result of the microbubbles.

Figure 4. Original Image of Elephant Toothpaste Flow on the Table

The photo was taken with 100 ISO, a focal length of 32 mm, an aperture of *f*5.6, and a 1/160s shutter speed. The field of view of this image is 38.42 degrees horizontally and 26.21 degrees vertically. Using darktable the image was post-processed to increase the contrast, highlighting the texture and creating more dimension within the image. The contrast was increased to emphasize the different colors more, and also to make the craters created by the popped bubbles more intense. I also messed with the saturation, hue, and color brightness to further enhance the colors, especially the rainbow effect seen in the bubbles on the righthand side of *Figure 1*.

Conclusion

The image beautifully shows the aftermath of the elephant's toothpaste and the bubbles that were created, and popped, as part of the reaction. The lines formed by the dye being dropped in as stripes, also add a beautiful element that help highlight the flow. I really like the colors of the image, and the flow of it even though its asymmetrical, but I wish I had gotten a more closeup picture that specifically focused on the unpopped bubbles that were formed. The image didn't show the main part of the experiment and fluid flow that formed, but more of the aftermath of it, which wasnt the original intention. In the future the experiment would be performed using either a higher concentration of hydrogen peroxide, and or a different catalyst to create a bigger reaction. I would also conduct the experiment with a simpler backdrop and better, more consistent, lighting to better highlight the flow and colors.

References

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