Team Project 2: Diffusion

Figure 1: Final image for team project 2.

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Introduction

The goal of this project is to visualize diffusion. We saw some work from Alberto Seveso and wanted to recreate his dye-in-water photographs. Our team is dropping water-based paint into a tank full of water. We will be able to watch the paint diffuse into the solution until it is a homogenous mixture. Joanna Bugajska, Quyncie Grenis, and Rob VanCleave all helped in the setup and pouring of the solute.

Physics

The fluid phenomena that our group is trying to observe is the strange structure that a solute displays when it is diffusing into a solvent. In this case, the paint is the solute and water is the solvent.

The paint was dropped from roughly 10 inches above the tank. A fluid dropping from this elevation has a fair amount of speed by the time it hits the water.

$$d = v_0 t + \frac{1}{2} a t^2$$

$$10\ inches = .254\ meters$$

$$.254\ m = \left(0 \frac{m}{s}\right) t + \frac{1}{2}\left(9.81 \frac{m}{s^2}\right) t^2$$

$$t = .228\ s$$

$$v = v_0 + at$$

$$v_0 = 0 \frac{m}{s}$$

$$v = \left(9.81 \frac{m}{s^2}\right)(.228\ s) = 2.24\ m/s$$

The paint had a velocity of 2.24 m/s as it hit the surface of the water. It is important to calculate the Reynolds Number of this fluid because the diffusion effects are largely based on the Reynolds Number. The paint was actually a mixture of paint and water, so the kinematic viscosity will have to account for both.

$$Re = \frac{VL}{v}$$

$$V = 2.24 \frac{m}{s}$$

$$L = charcteristic\ dimension\ \approx\ .01\ meters$$

$$v = kinematic\ viscosity = 1.004\ x\ 10^{-6} m^2/s$$

$$Re = \frac{VL}{v} = \frac{\left(2.24\frac{m}{s}\right)(.01\ m)}{1.004x10^{-6}\left(\frac{m^2}{s}\right)} = 22{,}310$$

This large Reynolds number means that the paint/water mixture is turbulent upon entry into the tank. When Re is small, the flow remains laminar and steady[1]. The point where the flow begins to spread out is known as the transition point[1]. As Re increases, the transition point moves further and further upstream[1]. When you look at my final photo, particularly in the white, you can see a small portion of flow that is actually above the transition point. Because we have a large Re, the solute immediately begins to spread out.

The solute, or dye, in my photo largely consists of water, which has a relatively large mass diffusivity coefficient[2]. This means that the dye will want to diffuse into the solvent very quickly, as it clearly does. If we had dropped the dye in slowly, we would have seen this same phenomena except it wouldn't be as clouded and there would be a stream before the transition point.

Experimental Setup

All group members used the following setup for their diffusion pictures. The tank was set on a table with two light sources facing the tank as shown in Figure 3 and 4. The paint was dropped from about 8-12 inches above the tank.

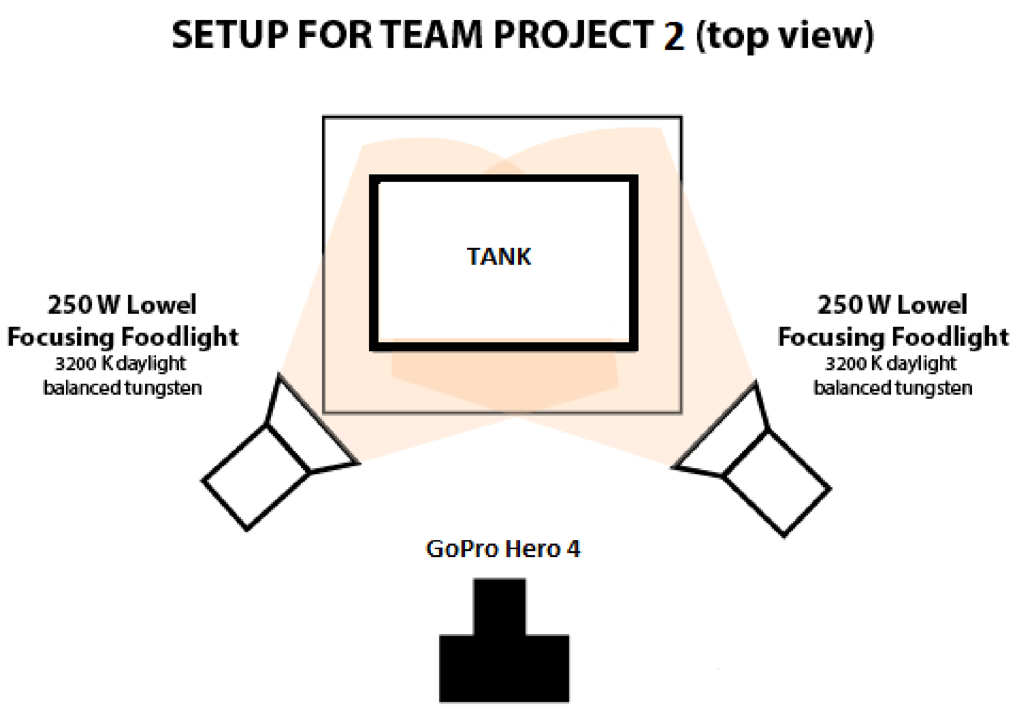

Figure 2: Diagram of setup.

Figure 3: Experimental setup for the video.

Image Capture

The original images are displayed below.

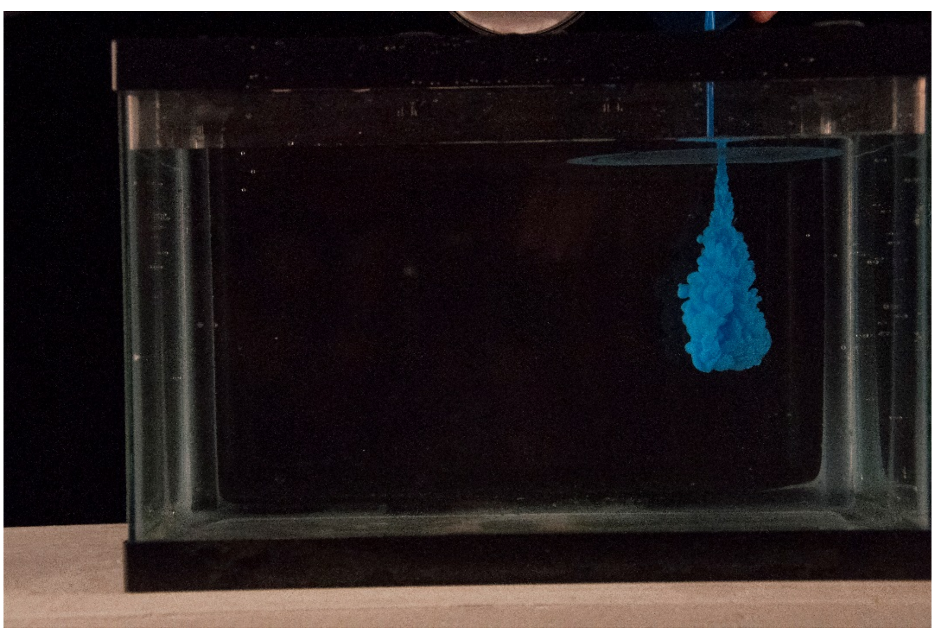

Figure 4: Unedited #1.

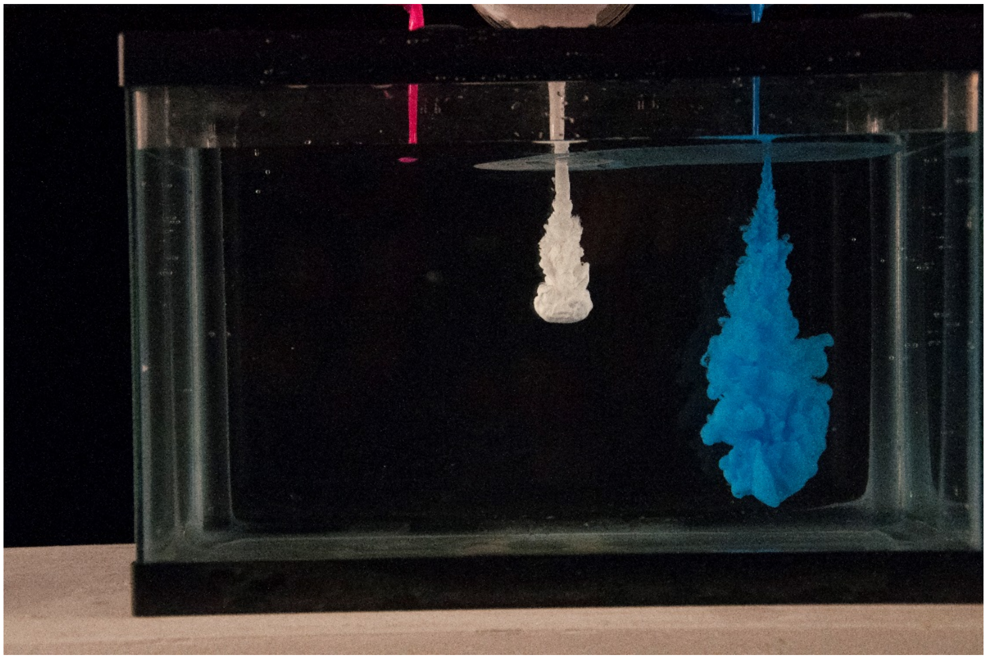

Figure 5: Unedited #2.

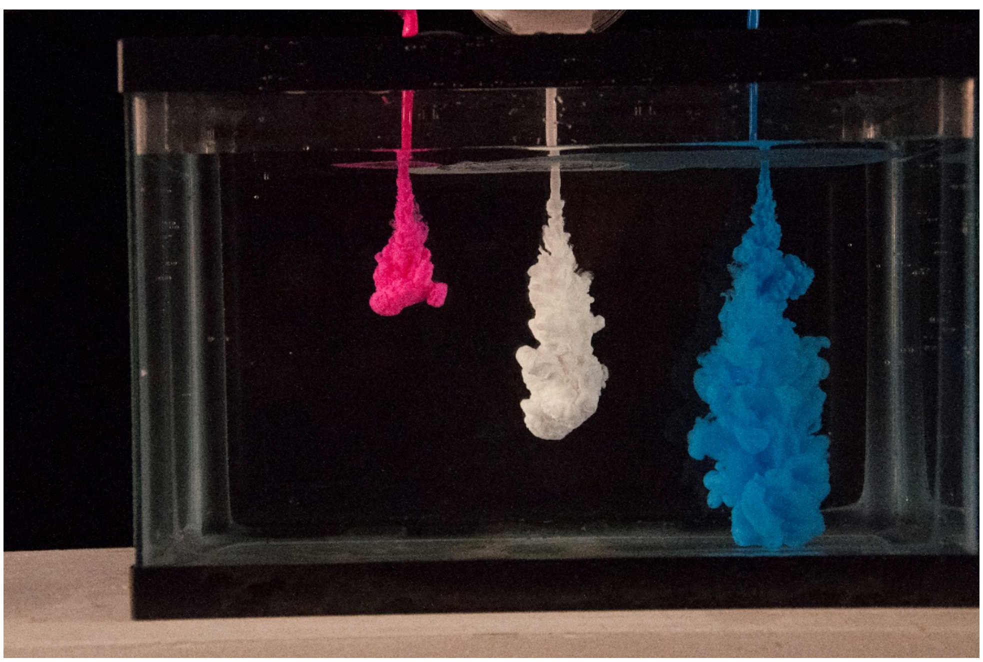

Figure 6: Unedited #3.

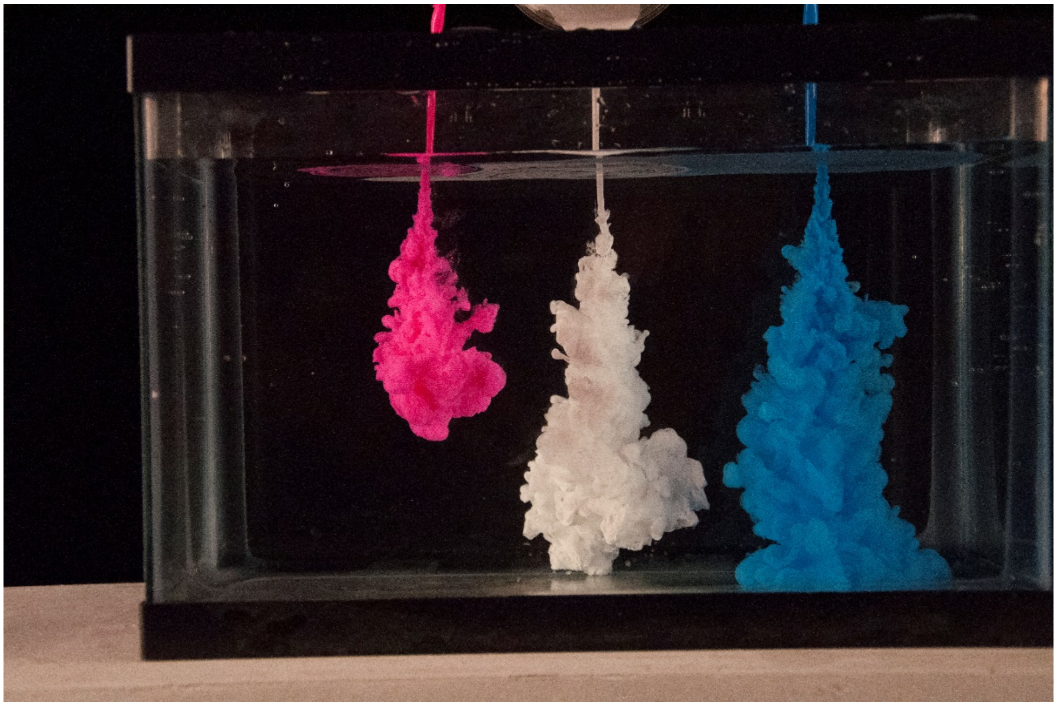

Figure 7: Unedited #4.

The images were taken into Adobe Photoshop and were cropped to take out the tank and other distracting elements. The GoPro that our group used has a fixed focus and aperture. We took four pictures per second. The timespan of my photo is a little more than one second because I didn't use consecutive pictures.

Conclusion

Diffusion occurs anytime a solute is introduced to a solvent. The elements of the solute are trying to disperse to create a homogenous mixture. I was able to capture the initial visualization of the diffusion of three different colors and I am happy with what I've learned.

References

1. Nakayama, Yasuki. Tanida, Yoshimichi. Atlas of Visualization II. Edited by The Visualization Society of Japan. CRC Press, Inc. 1996.

2. Wikipedia page on Mass Diffusivity <https://en.wikipedia.org/wiki/Mass_diffusivity>