**Team III: Blue Goo**

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## I. INTRODUCTION

The third team assignment was completed with help from Brandon Gushlaw, Peilin Yang, and Winston Douglas. The intent of this image was to demonstrate the flow of relatively viscous fluid through a channel. To do this, an apparatus was cut with several features including two entry ports to inject Elmer's glue. Elmer's glue was chosen for the experiment due to its dynamic viscosity of 2311 cP, which is equal to 2.311 Pa*s. With the fluid being injected into the apparatus relatively slowly, the image demonstrates how the viscosity and surface tension slows the process of the fluid cascading down into the next trough. The contact angle of the wetting fluid is determined by three different values: the surface tension of the wetting liquid (Elmer's glue), the surface tension of the solid surface (acrylic), and the solid-liquid interfacial tension (Law and Zhao, 2015).

## II. APPARATUS & FLUID MECHANICS

To capture this image, an apparatus was laser cut in the ITLL. This apparatus included black background plate and a clear acrylic cover plate. Sandwiched between these plates was a 1/8" thick acrylic that was laser cut to create a channel with two entry ports. These parts were fastened together using an epoxy, with a lack of epoxy above the peak so that air could escape as the fluid entered the channel. The dimensions of the channel can be seen below in *Figure 1*.

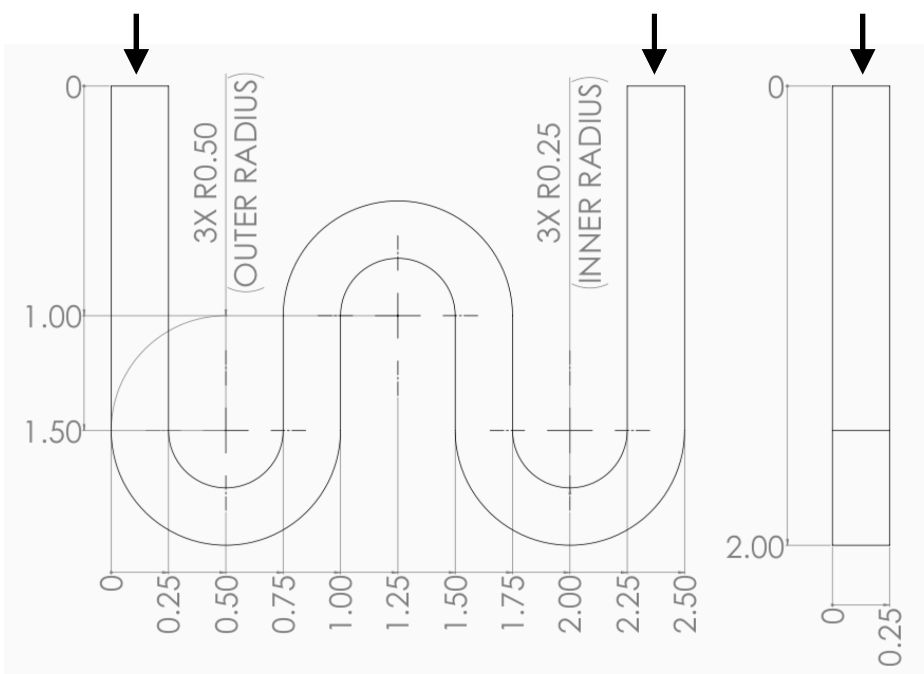


***Figure 1***: *Dimensions of fluid channel*

To inject the fluid into the channel, 25 mL of glue was sucked up into a syringe so that accurate injection could occur. As the fluid was injected into the channel, it eventually flowed over the peak in the middle of the apparatus following Bernoulli's Principle. As it cascaded gently into the next trough, a wetting angle of approximately 30° can be seen. This angle can be calculated using Young's equation:

$$\boldsymbol{\gamma}_{SV} = \boldsymbol{\gamma}_{LV} \cos\boldsymbol{\theta} + \boldsymbol{\gamma}_{SL} \quad , \qquad \textit{Equation 1}$$

*w*here $\boldsymbol{\gamma}_{SV}$ is the surface of the wetting liquid, $\boldsymbol{\gamma}_{LV}$ is the surface tension of the solid surface, and $\boldsymbol{\gamma}_{SV}$ is the liquid-solid interfacial tension (Law and Zhao, 2015). With an unknown $\boldsymbol{\gamma}_{SV}$, it is difficult to calculate a theoretical wetting angle to compare with the experimental wetting angle. This experimental wetting angle is drawn on the final image, *Figure 3* below.

## III. VISUALIZATION TECHNIQUE

To help with the visuals of this image, food coloring was added to the glue. 8 drops of food coloring was added to a half cup of glue to get the desired color. The experiment was performed in The Project Depot in the ITLL at the University of Colorado Boulder, which was well lit with overhead lighting. My black sweatshirt was placed behind the camera to reduce glare.

## IV. PHOTOGRAPHING TECHNIQUE

The camera used for this was an iPhone X. A video was taken of the flow, but I wanted to capture the fluid in an image. The video was taken with pixel dimensions of 3840 × 2160 and then a screenshot was taken to change the pixel dimensions to 2436 × 1125. Due to the unconventional way of taking this image, no other information is available. The original image can be seen below in *Figure 2*.

To enhance the image, the curves were changed to make the black areas completely black. Then, the clone stamp tool was used to remove the areas where the bubbles of the epoxy were still visible. The clone stamp tool was also used to clean up the areas where fluid had gotten stuck between the acrylic plates from previous runs through the experiment. The image was cropped and rotated to change the pixel dimensions to 1052 × 928. The image was then flipped left to right, so that the direction of the flow was the direction that you read, left to right.

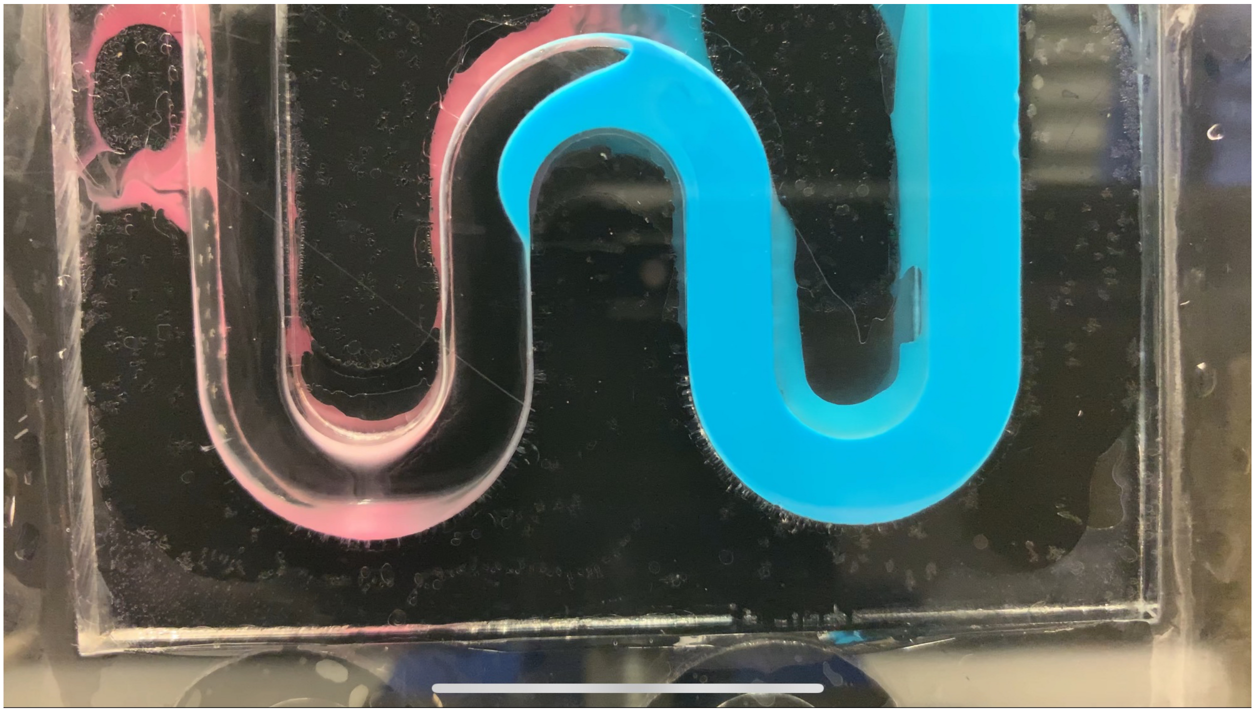

***Figure 2****: The original image*

## V. RESULTS

The final image can be seen below in *Figure 3*. I am happy with the editing I performed in photoshop. I think seeing the flow on a completely black background gives a minimalist feel to the image that completely makes the flow the focus of the image. While my team was able to create beautiful videos of the different flows, I think my image is able to capture the flow well and demonstrate the surface tension and wetting angle very well. To improve the image, I could get better at my steady hand in editing. I am not a fan of the choppy feel to the right side of the trough, especially since the channel was laser-cut to be perfectly circular.

I believe this image was my best work throughout the class, and my teammates and I ended with our most successful work of the semester.

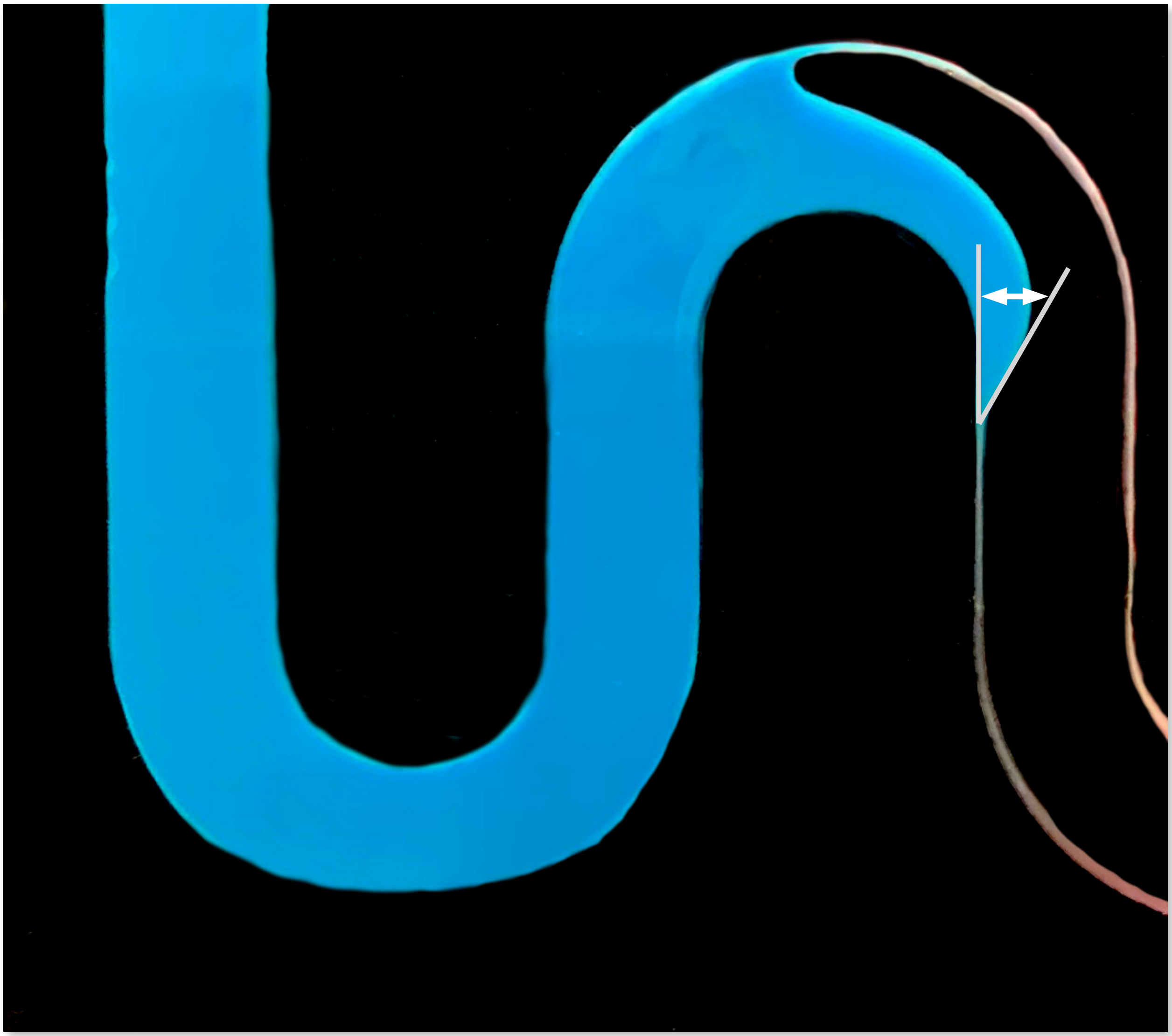

***Figure 3***: *The final image with the wetting angle, seen on the cover page without the wetting angle*

## VI. REFERENCES

Law, KY and Hong Zhao. "Wetting on flat and smooth surfaces." *Surface Wetting: Characterization, contact angles, and fundamentals*, Springer International Publishing, 2015, pp. 35-54.