Team First

By: Devin Sakamoto

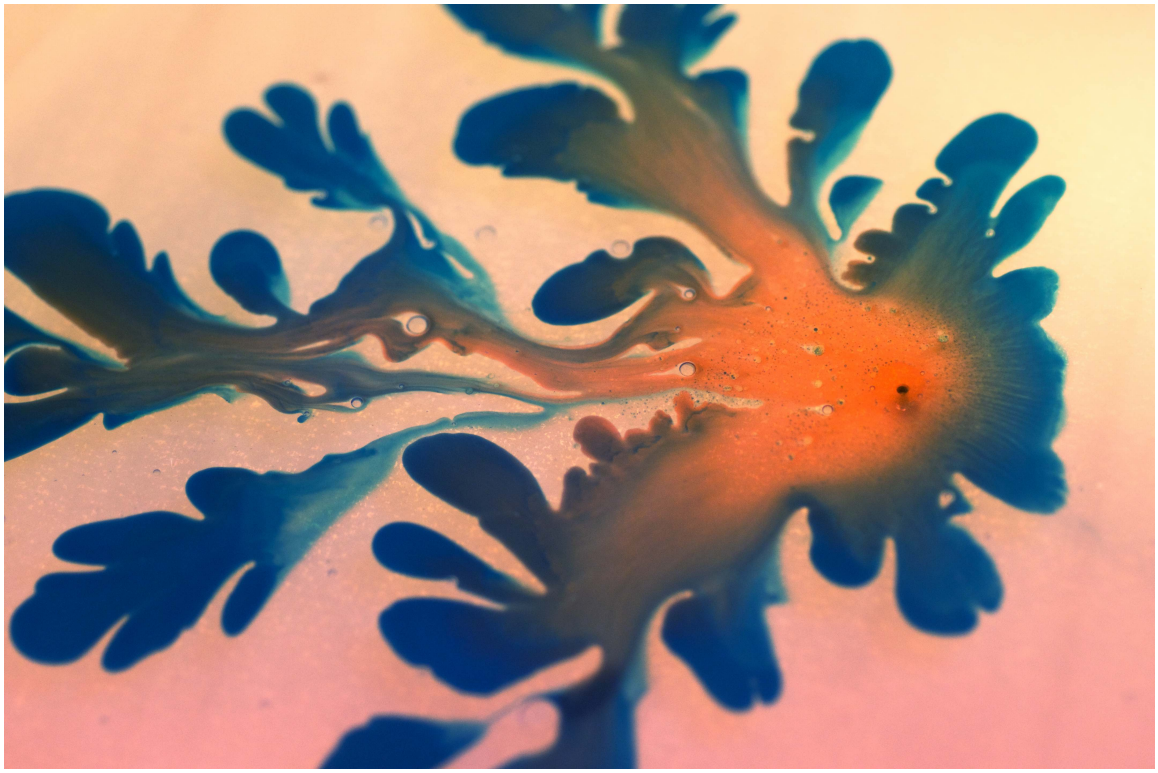

Figure 1: Final Image

Introduction

The purpose of this image is to illustrate the fingering effect brought by the Saffman-Taylor instability using a Hele-Shaw Cell setup. The image could not have been made without the assistance of Isis Peguero, Elizabeth Whitman, and Brandon Deneen. The setup was complicated and required multiple pairs of hands to prepare, initiate, photograph, and clean up the Hele-Shaw cell.

Background

This image uses a Hele-Shaw cell to create Saffon-Taylor instabilities. A Hele-Shaw cell consists of a domain with a very small gap in one direction, z, and much larger dimensions in the other two dimensions, x and y. Saffon-Taylor instabilities are formed when a less viscous fluid is forced through a more viscous fluid in a Hele-Shaw cell. Elements that affect these instabilities are the size of the gap, the force that the less viscous fluid is added to the flow with, and the difference between the viscosities of the fluids.

Visualization Technique

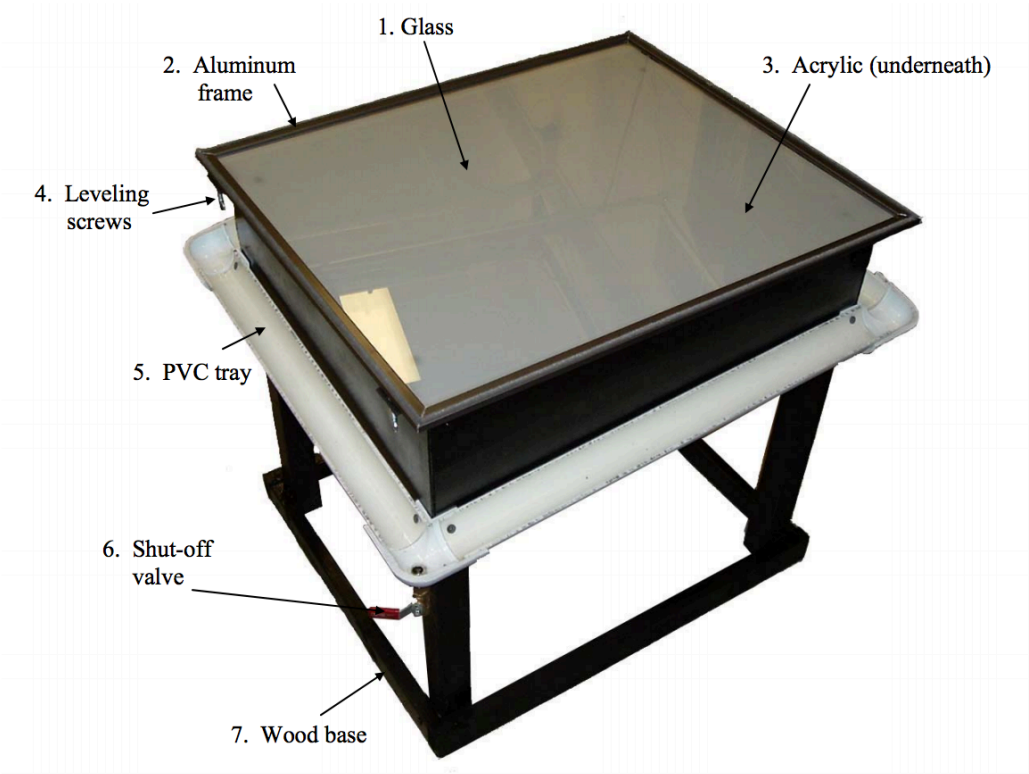

Figure 2: Hele-Shaw Cell Setup

The image used a premade radial Hele-Shaw cell setup shown in Figure 2. To start off, the leveling screws were all set so that the glass sat above the acrylic by 2 mm. In between this gap is where the actual flow takes place. Next, the more viscous fluid, in this case, clear Tide laundry detergent, was poured onto the center of the acrylic with the glass set off to the side. It is important to note that there is a small 2 mm diameter hole in the center of the acrylic that should be in the center of the viscous fluid. Enough of the viscous fluid was be poured on so that it forms a rough circle with a diameter of around 30 cm with the glass placed on top. Next, a 30 mL syringe was filled up with a less viscous fluid, blue milk, and attached to a thin tube that is then inserted into the previously mentioned small hole in the acrylic. Then push on the syringe to create the Saffman-Taylor instability. The syringe was filled again with red water and added the setup, too, to produce the multiple colors in the image. Both the water and milk were mixed with a ratio of a half-cup of fluid with 4 drops of food coloring. The image was taken outside at dusk with an outdoor light under the acrylic. The natural outdoor light was very dim to limit reflections, but bright enough still see what was happening. No flash was used.

Photographic Technique

The camera used was a Nikon D5000 DSLR with a macro lens. The macro lens was used because there were several small details in the flow. The lens focal length is 60 mm. During the image capture, the camera was about a foot away from the actual flow at about a 45° angle. Both the original and final images have pixel dimensions of 4288 x 2848. The aperture was set to f/3.5, the shutter speed was set to 1/200, and the ISO was set to 400. The light for the image was not too bright so these settings were set to increase the brightness. The aperture was set to f/3.5, a relatively large opening, to let in more light. The shutter speed was kept low to prevent any motion blur since the flow move slightly after the initial injection. The ISO is higher to add light. Post processing on the image was fairly minor. Only the colors were adjusted with the tool curves to bring out the contrast of the image. The original image is shown in Figure 3.

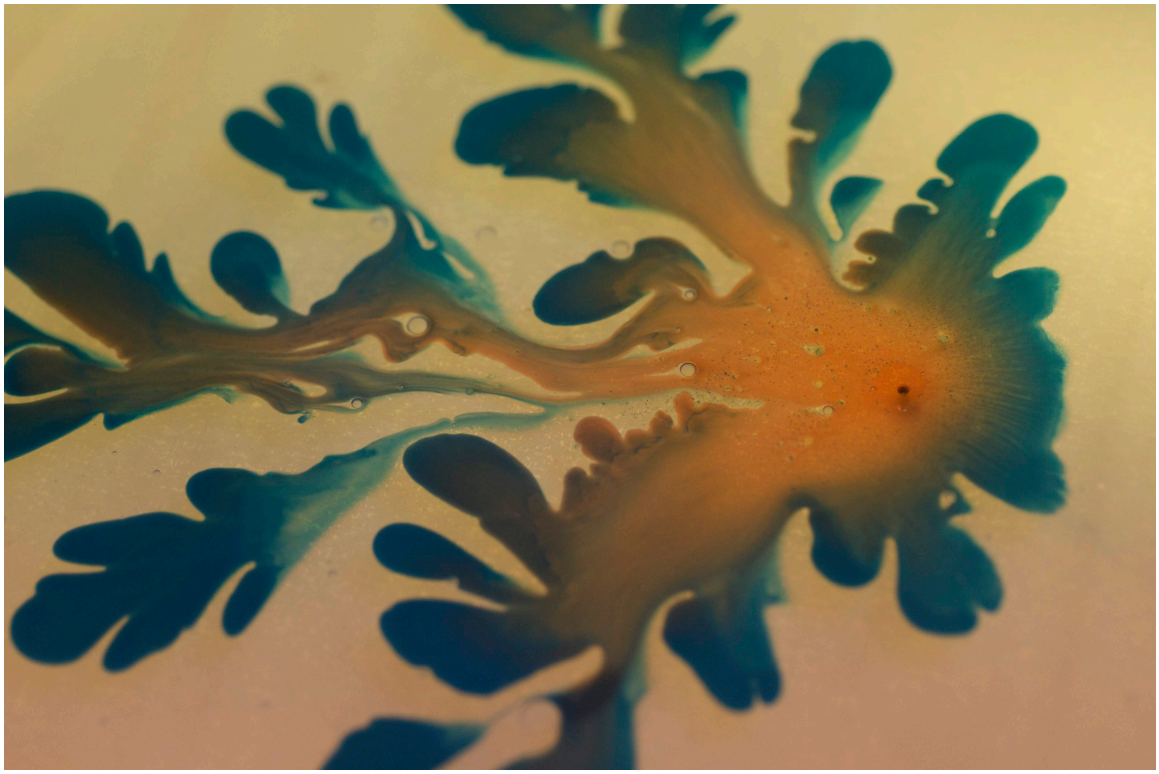

Figure 3: Original Image

Conclusion

The image is successful in showing the fingering effect brought on by the Saffman-Taylor instability. The fingering is clearly visible in the blue milk. Also, mixing between the water and milk is visible as streaks in between the two. Personally, I like the way the final image turned out. The colors look really appealing with each other. I also like the out of focus edges that the macro lens adds to the image. It would be interesting to expand on this flow. The glass could be angled to see the effect that has on the flow, or different fluids could be experimented with.

References

Kirby, Brian J. "Bounded Stokes Flows." *Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices*. Ithaca: Cornell U, 2009. N. pag. Print.

Tabeling, P., G. Zocchi, and A. Libchaber. *An Experimental Study of the Saffman-Taylor Instability*. *Fluid Mech.* Vol. 177. Chicago: James Franck Institute and E. Fermi Institute, 1986. 67-82. Web. 9 Nov. 2015. <http://www.math.fsu.edu/~moore/SeminarFiles/SaffTaylor87.pdf>.