Team First Image

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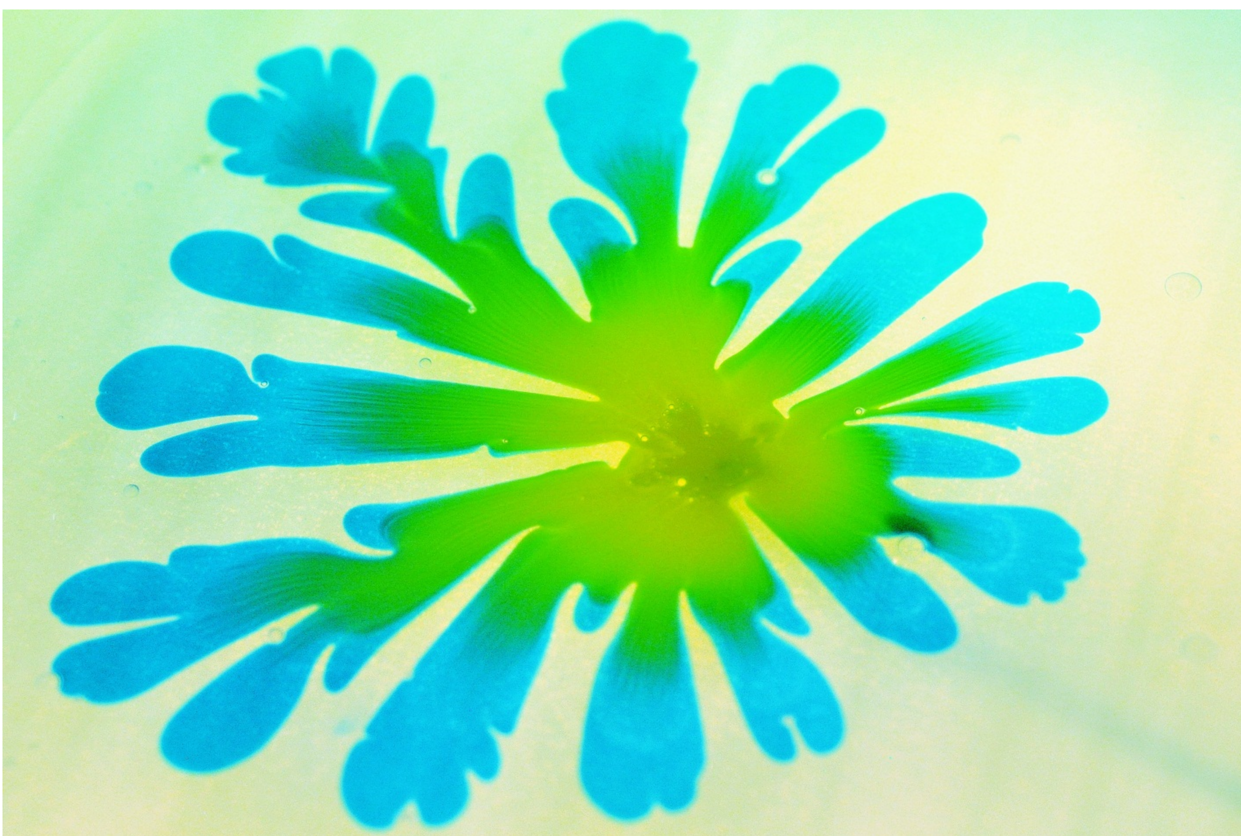

This image was taken to as a part of the first team image assignment for the class. The group decided to use a hele-shaw cell as the subject for the image. The team used many different fluids figuring out which ones work best. The image was taken by Devin Sakamoto while the experiment was run.

The hele-shaw cell was set up using a small table that had an opaque piece of acrylic as the top surface. The acrylic had a small hole in that allowed for a small piece of copper pipe to inject the fluid into the system. The small pipe was attached to a 10 cc syringe via a flexible tube. The syringe was used to hold and inject the different fluids. In each corner of square table there was a bolt that was used to hold up a thin sheet of glass that sat at a height of 1.5mm. The less dense fluid was prepped in the syringe and all of the air was flushed out of the tube and the pipe. The pipe was then inserted into the hole. The more viscus fluid was then poured onto the acrylic and then the glass sheet was placed on top. Next the plunger on the syringe was depressed and the less viscus fluid was injected into the system. A diagram of the system is shown below in figure 1. The experiment was carried out outside and at the time the temperature was approximately 20 deg c.

Figure 1 Hele-Shaw Cell Table[1]

This image captures the phenomenon of viscous fingering. The fingering is a result of the unstable interface between the two fluids. It occurs when the less viscous fluid (milk) is injected into the more viscous fluid (detergent) creating a Saffman-Taylor Instability. If the process was repeated with the fluids reversed both the fluids would expand radially instead of the fingers forming. This phenomenon is also known as the sampan-Taylor instability. This most commonly found in the Hele-Shaw geometry and the mathematics are best described by the Darcy's law. This law models the flow of a fluid through a porous medium. The equation for the law is shown below.

$$Q = \frac{-\kappa A(p_b - p_a)}{\mu L}.$$

Equation 1 Darcy's Law

In this equation Q is measured in volume per unit time or in this case 2cc/s. The K value is the permeability of the medium while A is the cross sectional area of the boundary layer. The pressure values inside the parenthesis account for the total pressure drop. In the denominator the two variables are the viscosity of the liquid and the length of the pressure drop. [5]

The calculation for the Reynolds number of the milk is as follows. The density of milk at 20^{o}c is accepted to be 1.035 g/cm^2.[2] The team estimated the velocity of the fingers to be 1cm a second and each finger is approximately 10 cm long. The viscosity of milk is 3cps. [3]

$$Re = \frac{\rho V L}{\mu}$$

$$Re = \frac{1.035 \frac{g}{cm^2} * \frac{1cm}{s} * 10cm}{3cps}$$

$$Re = 3.45$$

This number is much lower than the critical number of 14000 that is the cutoff for turbulent flow between two parallel plates. This is good because if there was turbulent flow the fluid may have mixed and the fingers would not have been created.

In the image the team used clear laundry detergent and injected 10 cubic centimeters of milk mixed with blue food dye. Once that was depleted the team reloaded the syringe and process with milk mixed with yellow food dye. The experiment was carried out above a light. The light was an outdoor light that is commonly used to illuminate trees. This allowed for a bright neutral light to shine through the opaque acrylic.

The field of view of the image is 8 inches by 7 inches. The distance of the subject from the lens is just over a foot and a half. The focal length was 60mm and the camera used was a Nikon D5000. The image is 3825 pixels by 2843 pixels. The aperture was 3.4 and the f-stop for the image was f/3.5. The image was taken with plenty of light and the ISO setting was 800 with a shutter time of 1/200sec. The original image prior to post processing can be shown below. The post processing that was done was simple but the result was a much more striking image. Using the tone curve the white corner was brought in to help wash out the yellow of the protective layer on the acrylic. The contrast and brightness were increased to help the differentiate between the different colors in the experiment.

This image revels the Saffman-Taylor Instability of the mixing between two fluids with varying viscosity. The fluid physics show above are easily evident in the image and the image helps an individual understand what happens by giving them a visual presentation to the physics. If I could change anything about the image I would have increased the depth of the focal plane. This would have enabled for more of the hele-shaw cell to be in clear focus and would have resulted in more definition in the lower right hand part of the cell.

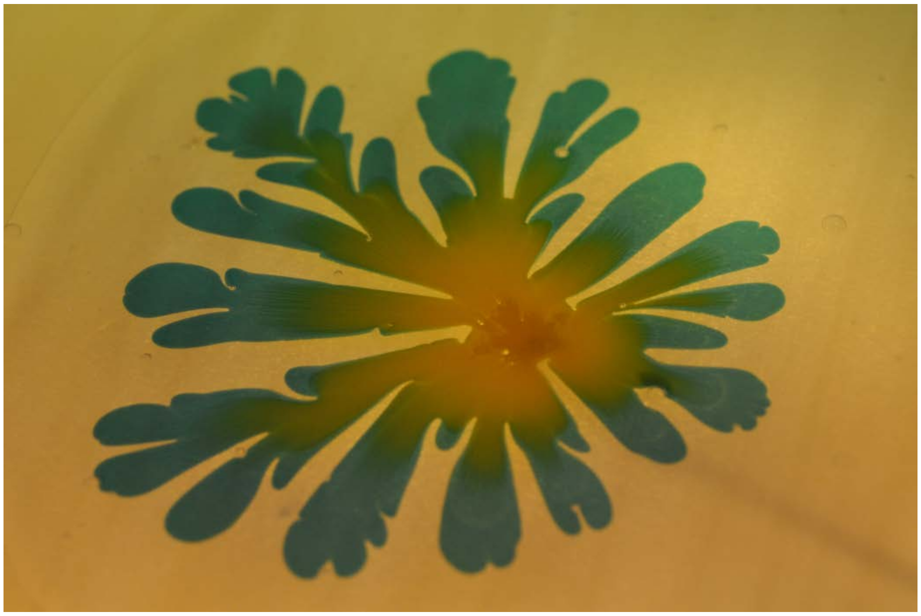

Figure 2 Original Image

1 Setup Diagram

Hertzberg, Jean. Saffman-Taylor Instability Machine - User's Manual. 4 May 2015. <http://www.colorado.edu/MCEN/flowvis/course/SaffmanUser.pdf>

2 Density of milk

Elbert, Glen, and Alicia Noelle Jones. "Density of Milk." Density of Milk. N.p., 2002. Web. 06 Nov. 2015. <http://hypertextbook.com/facts/2002/AliciaNoelleJones.shtml>.

3 Viscosity of milk

"Viscosity Tables." Viscosity Tables. V&P Scientific, Inc, n.d. Web. 06 Nov. 2015. <http://www.vp-scientific.com/Viscosity_Tables.htm

4 Viscus Fingering

"Viscous Fingering." Wikipedia. Wikimedia Foundation, n.d. Web. 06 Nov. 2015. <https://en.wikipedia.org/wiki/Viscous_fingering>.

5 Darcy's Law

"Darcy's Law." Wikipedia. Wikimedia Foundation, n.d. Web. 06 Nov. 2015. <https://en.wikipedia.org/wiki/Darcy%27s_law>.