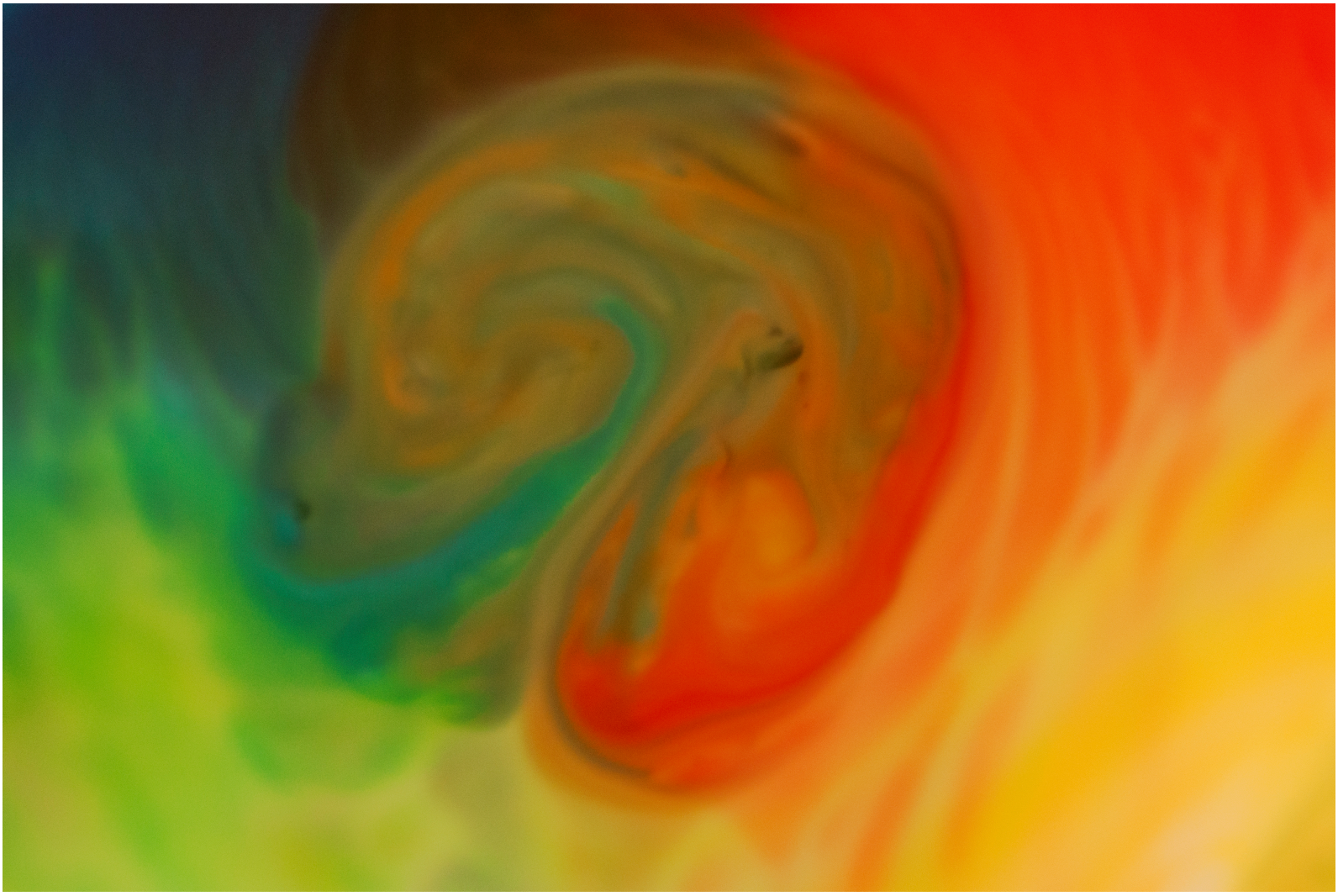
Team Assignment #2 Write-Up

Blake Buchannan

Flow Visualization – MCEN 5151

4/9/13



I. Introduction

For Team assignment #2, my goal was to use an experiment that allowed me to take another macro photo of an interesting flow phenomenon. My macro photo from Team Assignment 1 turned out so well that my goal was to match it or improve upon it. I came across a great flow experiment while researching possibilities, sometimes referred to as the "magic milk experiment". The experiment can be summarized by first placing food coloring in a dish of milk, and then placing dish soap in the dish, which in turn dissolves the fat molecules of the milk, therefore lowering the surface tension in that area. The lowering surface tension creates a flow across the top of the milk, which is easily demonstrated by the food coloring. These great flows and color combinations created in the milk are what I was trying to capture in this image.

II. Flow Apparatus

As mentioned in the introduction, to begin, several drops of food coloring are placed in a stagnant dish full of milk. This can be seen in Figure 1.

Figure 1 - Preliminary setup: food coloring in milk

The next step in the experiment is to place a small amount of dish soap in the dish. I did this using a Q-tip cotton swap that was dipped in dish soap. In order for this experiment to work, the milk cannot be skim; it needs to have fat in it in order for the soap molecules to react with the milk. I used 1% milk, which worked; however using whole milk would be better in the future. Once the cotton swap with the dish soap was placed in the center of the dish, as can be seen in Figure 2, the reactions between the soap and milk began happening immediately.

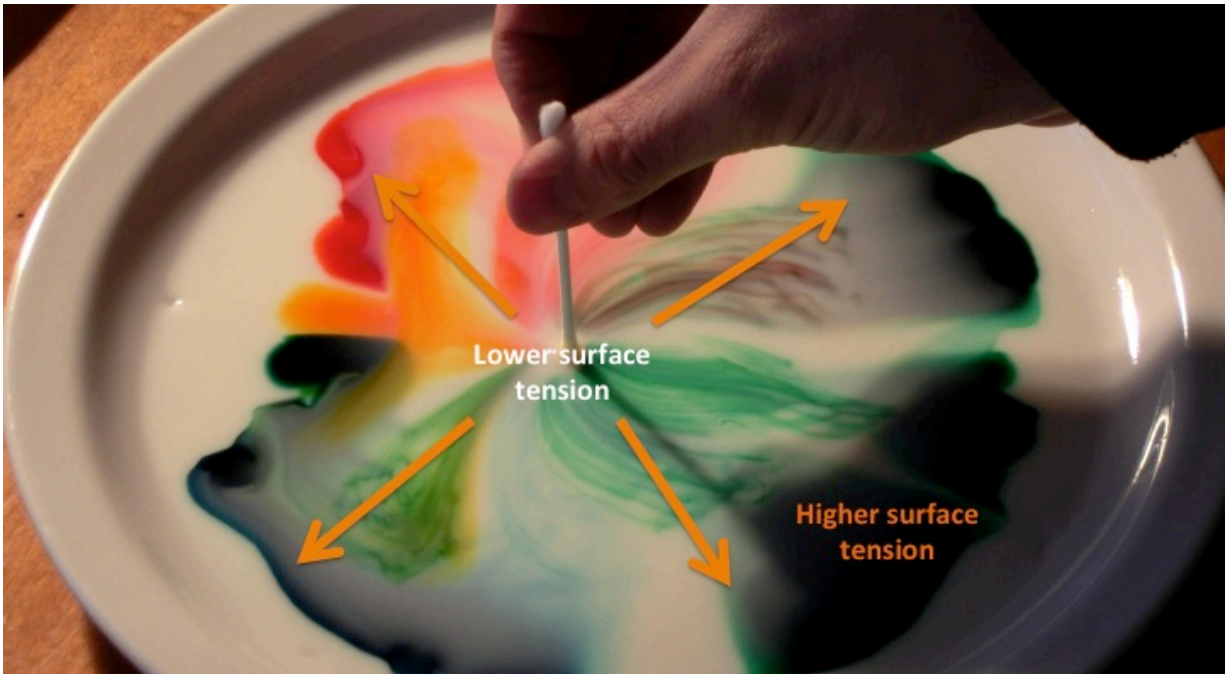


Figure 2 - Initial interaction of the dish soap and milk

What is occurring in this experiment is occurring at a molecular level. The dish soap, because of its bipolar characteristics, weakens the chemical bonds that hold the proteins and fats in solution. The soap's polar, hydrophilic end dissolves in water, and its hydrophobic end attaches to a fat globule in the milk. The molecules of fat distort in all directions as the soap molecules try to join up with them [1]. The soap then dissolves the fat molecules that they attach to, causing a lower surface tension in the immediate area. The surface of the milk outside the soap drop has a higher surface tension, so it pulls the surface away from that spot, causing the streaming effect of the food coloring seen in Figure 2 [2].

The streaks of food coloring move fairly slowly, and by analyzing the video taken of the experiment, which was taken at 30 frames per second, the streaks of food coloring moved 2.5 inches, which is 6.35 cm, in one second. This yields a fluid velocity of 0.0635 m/s. Using this velocity, the Reynolds number of the fluid can be calculated. In this case in particular, the Reynolds number could be calculated using the flow in an open channel formula.

$$\mathrm{Re} = \frac{R\rho \mathrm{v}}{\mu}$$

Where ρ is the density of the fluid, R is the hydraulic radius, v is the velocity of the fluid, L is the traveled length of the fluid, and μ is the dynamic viscosity of the fluid. In this case the density of the 1% milk is roughly $\rho = 1{,}033\ {}^{\mathrm{kg}}/_{\mathrm{m}^3}$, the velocity was found to be $\mathrm{v} = 0.0635\ {}^{\mathrm{m}}/_{\mathrm{s}}$, the hydraulic radius is roughly R = 0.0462 m, and the viscosity of the milk is μ = 0.003 Pa*s [3][4]. This yields a Reynolds number of:

$$\mathrm{Re} = \frac{(.0462\ \mathrm{m})\left(1{,}033\ {}^{\mathrm{kg}}/_{\mathrm{m}^3}\right)\ \mathrm{x}\ (0.0635\ {}^{\mathrm{m}}/_{\mathrm{s}})}{0.003\ \mathrm{Pa} * \mathrm{s}} = \mathbf{1{,}010}$$

This shows that the flow is laminar, since the cylindrical channel requires a Reynolds number of 10,000 for turbulence.

The actual image was taken after the Q-tip was in the milk dish for several minutes and the colors had spread evenly throughout the dish. The Q-tip was then quickly dipped back into the dish and then pulled out, and the picture was taken at the place where the Q-tip was dipped, leaving the flow seen in the image.

III. Visualization Technique

In order to better visualize the flow occurring in the milk, several drops of food coloring were initially placed in the milk at different locations and in different colors. As the surface tension was lowered in the area with the dish soap and the higher surface tension on the outer edges of the dish pulled the milk outwards, the streaking of the food coloring

enabled easy viewing of the flow movement. Only two drops of dye were placed in the milk at each location seen in Figure 1. For example, the red dye location had two drops of red dye; the orange location had one drop of red and one drop of yellow dye, and was continued for all eight drop locations. One small construction light was placed over the milk dish in order to provide enough lighting for the image.

IV. Photographic Technique

A 12.3 megapixel Nikon D90 DSLR was the camera used for this photo which yielded a photo 4288 × 2848 pixels. The reverse macro technique was utilized in order to take the macro fluid image, which means that a lens was disconnected from the camera, rotated around backwards, and held manually up to the camera body, which surprisingly acts as a macro lens. Due to the fact that the camera was not connected to any lens, the camera would not focus or set the settings for the photo so a manual aperture on the lens had to be set and manual photo settings on the camera body as well. The lens used was a Nikkor 50mm f/1.8. The manual settings chosen were a shutter speed of $^1/_{320}$ sec, an ISO of 500, and an aperture of f/1.8.

The image was taken in RAW format, and Adobe Photoshop CS5 was used for post processing. Various color balances were changed, the image was cropped, and the curves and levels were altered, as well as contrast. The main goal was to make the various colors of the fluid really pop, while ensuring a realistic image. The before and after images can be seen below in Figure 3

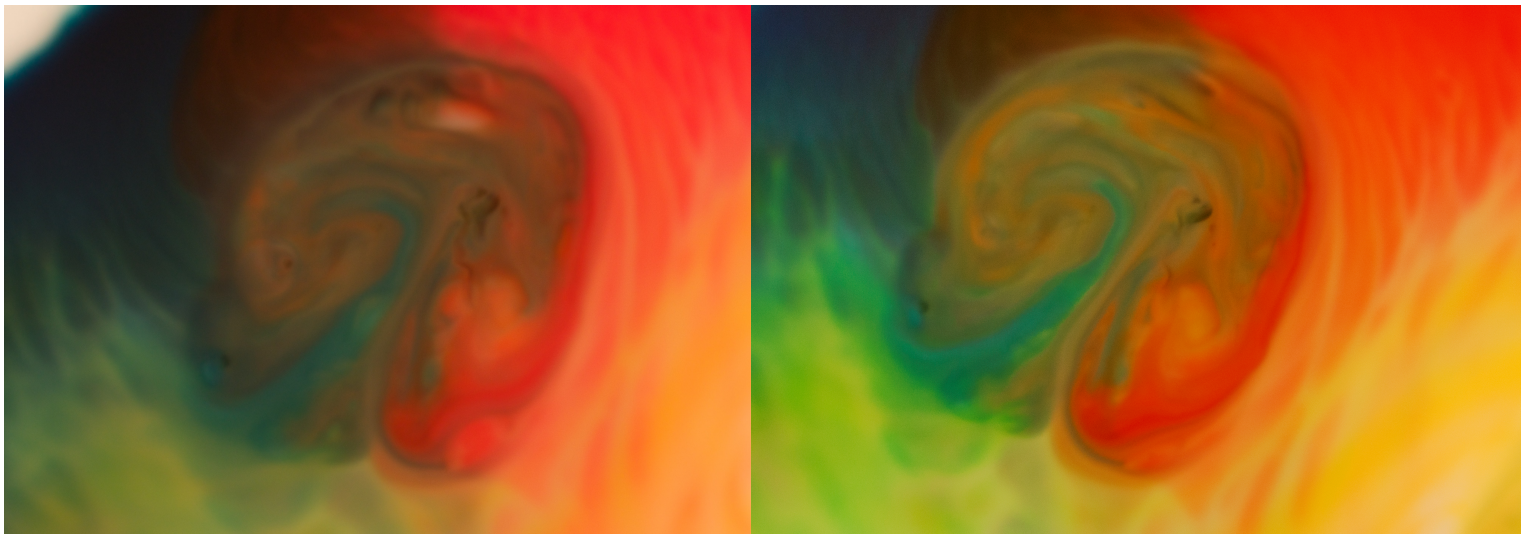


Figure 3 – Before (left) and after (right) post-processing image

V. Conclusion

In the end, I was fairly pleased with the result. I don't think that the picture was quite as good as my photo for Team assignment #1, however I it shows a very interesting blend of colors and a unique flow pattern. I wish that the boundaries of the flow were a little sharper, however the gradual change is also easy to look at. Next time, I would be sure to use whole milk to get an even larger reaction from the soap; I would also use more food coloring. Another good possibility would be to use a clear container to put the milk in, as opposed to the solid white plate that I did. This could allow you to see the interactions beneath the surface.

Special thanks to my roommate Ben Reed for the assistance with the experiment.

Sources

1. "Color Changing Milk." Steve Spangler Science. http://www.stevespanglerscience.com/experiment/milk-color-explosion (accessed April 7, 2013).
2. Anderson, David. "Tie-Dyed Milk." Cool Scienve. http://www.coolscience.org/CoolScience/KidScientists/tiedyemilk.htm (accessed April 7, 2013).
3. Jones, Alicia. "Density of Milk." The Physics Factbook. http://hypertextbook.com/facts/2002/AliciaNoelleJones.shtml (accessed April 7, 2013).
4. " APPROXIMATE VISCOSITIES OF SOME COMMON LIQUIDS." Michael Smith Engineers. http://www.michael-smith-engineers.co.uk