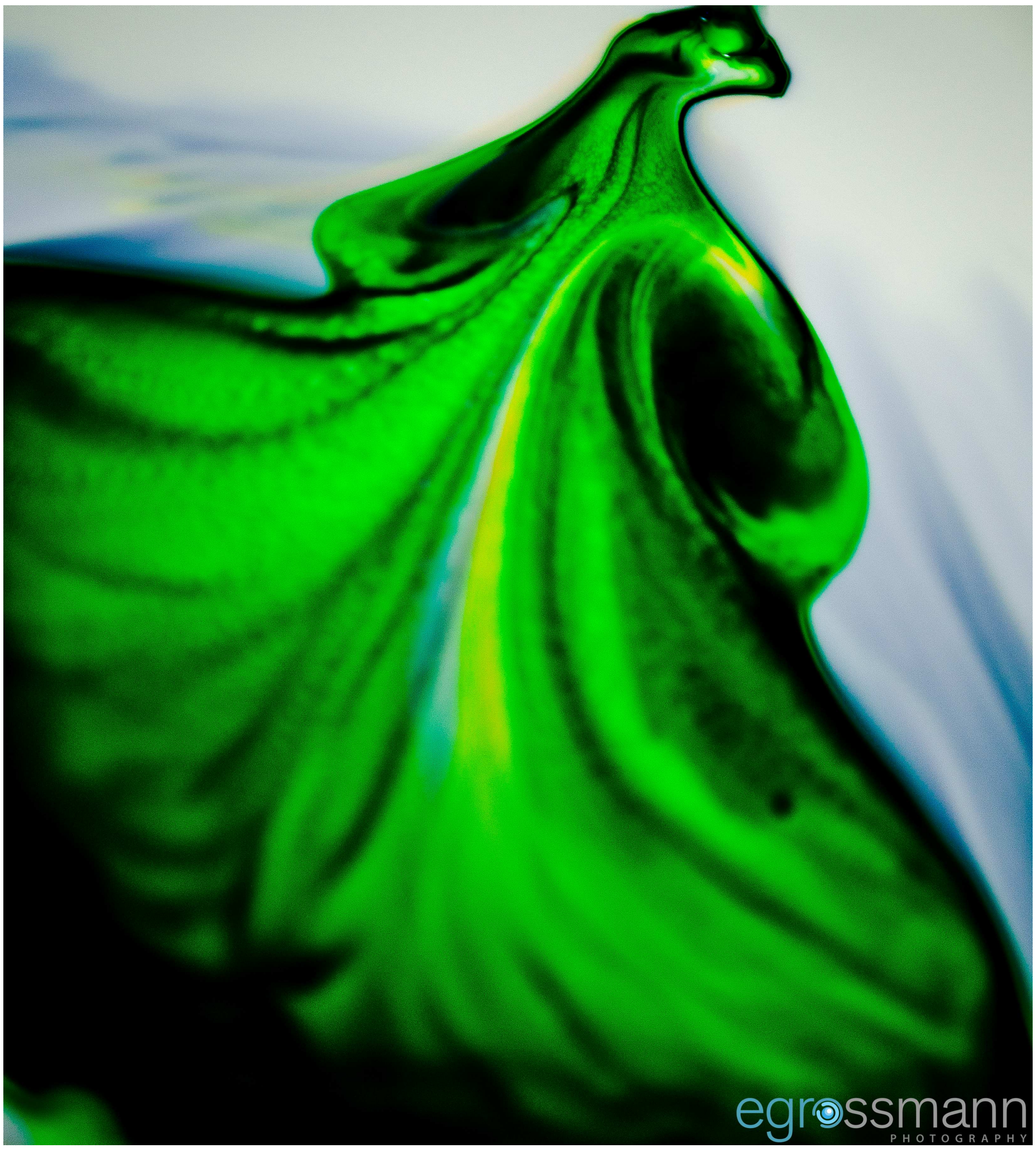
Flow Visualization
Team Project # 2

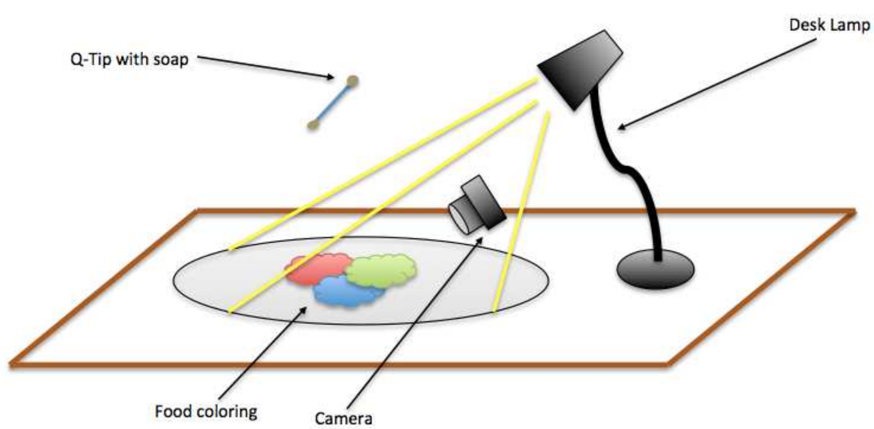
# *Psychedelic Milk*




***Ernesto Grossmann***
*M.S. Mechanical Engineering*

The main purpose of this image was to observe the psychedelic reaction between the combination of milk, food coloring and dish soap. When these three are mixed, an explosion of colors and shapes over the entire surface of the milk can be noticed. The main driver of this reaction is the dish soap, which is a combination of surfactants[1], that combined with the fat and proteins of the milk creates an interesting outcome as seen in the image that was captured for this project. Although the experiment seems extremely simple to execute, the chemistry and physics behind this phenomenon is what makes this experiment fascinating. Many attempts were necessary to obtain the desired image. Also, a different approach was taken regarding the pouring of the soap into the milk-food coloring mixture. Instead of pouring the soap directly over the milk, a cotton swab (Q-tip) filled with dish soap was used.

To capture the colorful phenomenon, a rectangular glass Pyrex container (3" deep) was used to hold in the milk. A conventional desk lamp with white light was placed on the east side of the container, pointing west (Fig. 1). The lighting was changed many times from place to place due to its intensity, therefore, creating shadows that were undesirable for the image. Also, many images were taken from diverse angles to capture the right image, but the final image was taken 8" away from the milk with the light coming from the back.




**Experiment ingredients:**

- Dish soap
- Q-tips
- Food coloring
- Whole milk
- Glass pyrex
- Desk lamp

**Figure 1.** Experiment apparatus sketch

[1] Compounds that lower the surface tension of a liquid, the interfacial tension between liquids, or that between a liquid and a solid.

During the experiment, food dyes in several configurations and combinations were added together with different Q-tips placements over the domain to find the most attractive effect. After many tries, the most interesting effect appeared when the Q-tip was translated while also rotated across the domain, creating swirling vortex shapes behind its path (Fig. 2). To better understand the behavior behind this effect, it is necessary to explore the physics behind the interaction of a surfactant with, in this case, milk. Milk is compound mainly by water, but still has vitamins, minerals, proteins, and small particles of fat. Also, depending on the type of milk used, the behavior of the reaction will vary due to the content of the fat in the solution. For example, skim milk posses more water than whole milk to reduce the fat content in the solution. Therefore, our concerns in this study are the fats and proteins contained in the milk because of the weak chemical bonds that hold these two elements together to the whole milk structure. So, by adding the dish soap to the equation, a micelle or cluster is formed, causing a sudden turbulence on the flow as the soap breaks down the fat molecules in the milk [1]. Since the fat is insoluble in water, the micelle, which has both hydrophilic[2] and hydrophobic[3] characteristics, attaches to the fat molecule to its hydrophilic head while its hydrophobic tail is forced inward away from the water [2]. The expansion will evolve until the soap and the fat are evenly distributed, and then stop leaving a mind-blowing display of amazing shapes and colors. Also, it is important to point out that the concentration of the soap is indispensable in the formation of the micelles, which is better known as the critical micelle concentration (CMC) [3]. Regarding the food coloring, its main function in the whole process is to make visible

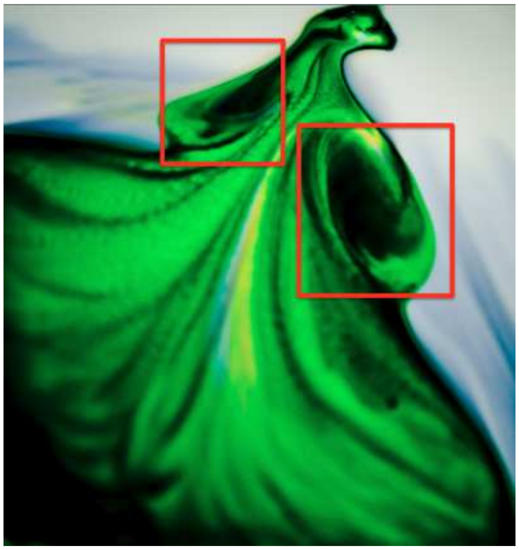


**Figure 2.** Vortex formations

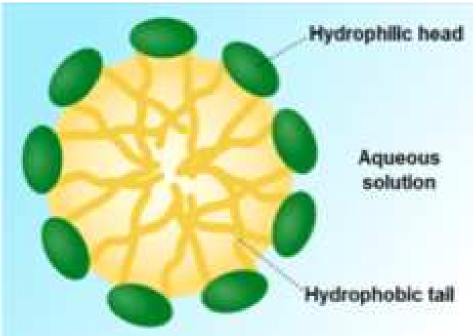



**Figure 3.** Micelle shape

[2] Substances that love water

[3] Substances that reject water

the whole fat-soap breaking expansion. As mentioned before, the soap as a surfactant breaks the surface tension of the milk by dissolving the fat molecules, promoting the food coloring mixing. However, the stronger surface region surrounding the liquid pulls away the surface from the weak region created by the soap.

Now, besides the milk-food coloring-soap reaction, a particular interest resides on the wake created by spinning and moving the Q-tip through the domain. It can be seen form the image that the wake created is somehow steady due to the low Reynolds number. These formations can be attributed to the well-known Von Karman's vortex wakes (Fig. 4). By calculating the Reynolds number[4], it is possible to approximate the flow regime and estimate the vortex wakes. Unfortunately, no data was gathered at the instant of the picture in order to approximate a Re number value, however, based of the vortex formations, it can be said that the values were around Re=49-194, which is considered a laminar vortex shedding [4].

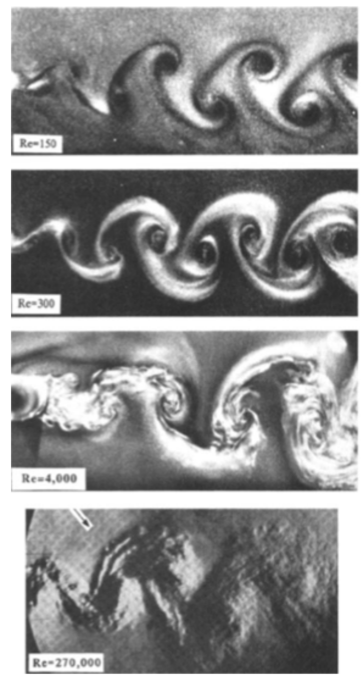



**Figure 4**. Von Karman wakes at different Re numbers

**Table 1.** Image Information

| | |
|---|---|
| Date | March 21st, 2012 6:00 pm |
| Camera | Nikon D5100 DSLR |
| Lens | Nikkor 18-55 mm f/ 3.5-5.6 |
| ISO | 200 |
| Shutter Speed | 1/80 sec. |
| Focal Length | 42 mm |
| Aperture | f/ 5.3 |

The picture was taken inside a room with artificial light as was mentioned at the beginning. However, as Table 1 shows, the low ISO 200 is mainly because of the harsh light that was used for this experiment. Also, a low aperture number was chosen because no

4 $R_e = \frac{VL}{\nu}$

depth of field was needed for this particular image. The image was enhanced in Adobe Lightroom 3. The image was first cropped and the contrast, vibrance, saturation, clarity and temperature were later enhanced. In addition, the original image showed the Q-tip in the frame, however, the choice was made, and the Q-tip was removed by applying the cloning tool. As an additional remark, the camera was set to focus on one point instead of providing a weighted average of the whole frame. By doing this, the image was focus close to the Q-tip while the rest remained softly blurred. The following images show the process undertook:

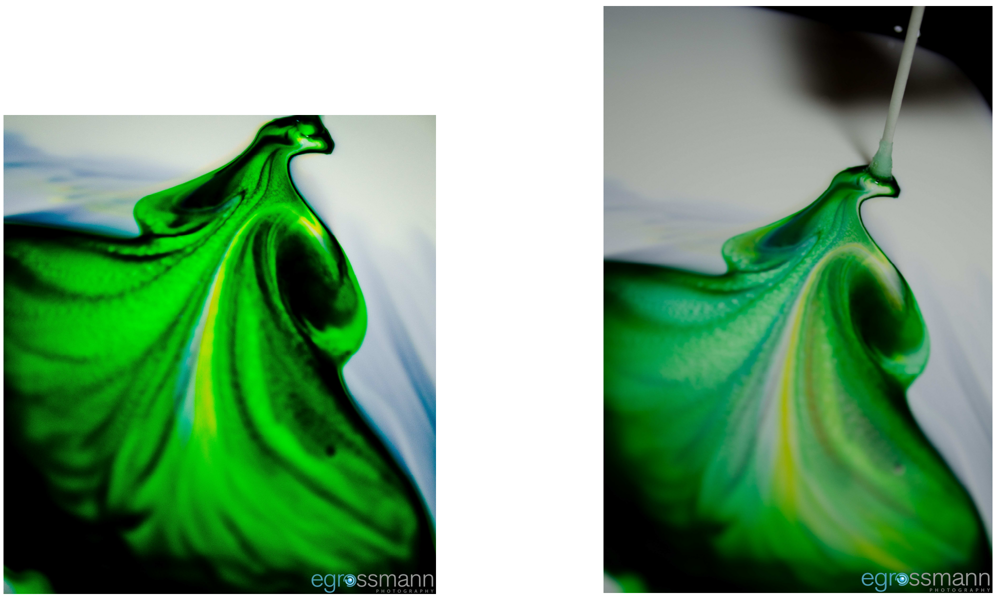



**Figure 5.** Enhanced image (left) and original version (right)

Finally, the image reveals accurately the nature of the dish soap as a surfactant by breaking the surface tension of the milk, which is composed primarily by water, fats, vitamins, proteins and minerals. Additionally, it reveals accurately how the food coloring follows the turbulent flow created by the rupture of the chemicals bond of the fat and proteins. I really do not dislike anything about the picture. For that matter, the fact that the image showed Von Karman wakes is somewhat fascinating. For future work I would like to try the same experiment by heating the milk to different temperatures in order to reduce the surface tension. Furthermore, I would like to find a way to control the reaction by pouring the same amount of dish soap at the same location for different tries, in order to estimate a certain behavior.

## *References*


[1] Mater, S., & Hurlburt, L. (n.d.). *Magic milk*. Retrieved from http://www.nipissingu.ca/education/jeffs/4284Winter/PDFS/MagicMilk.pdf

[2] Stangler, S. (n.d.). *Color changing milk*. Retrieved from http://www.stevespanglerscience.com/experiment/milk-color-explosion

[3] Rosen, M. (2004). *Surfactants and interfacial phenomena*. (3 ed.). New Jersey, NJ: John Wiley and Sons, Inc. Retrieved from http://www.scribd.com/doc/52668446/Rosen-M-J-Surfactants-And-Interfacial-Phenomena

[4] Williamson, C. H. K. (1996). *Vortex dynamics in the cylinder wake*. Manuscript submitted for publication, Retrieved from http://www.annualreviews.org/doi/pdf/10.1146/annurev.fl.28.010196.002401