Team Project #2 Report

4/23/12
MCEN 4151
Flow Visualization: The Physics and Art of Fluid Flow
Sam Sommers

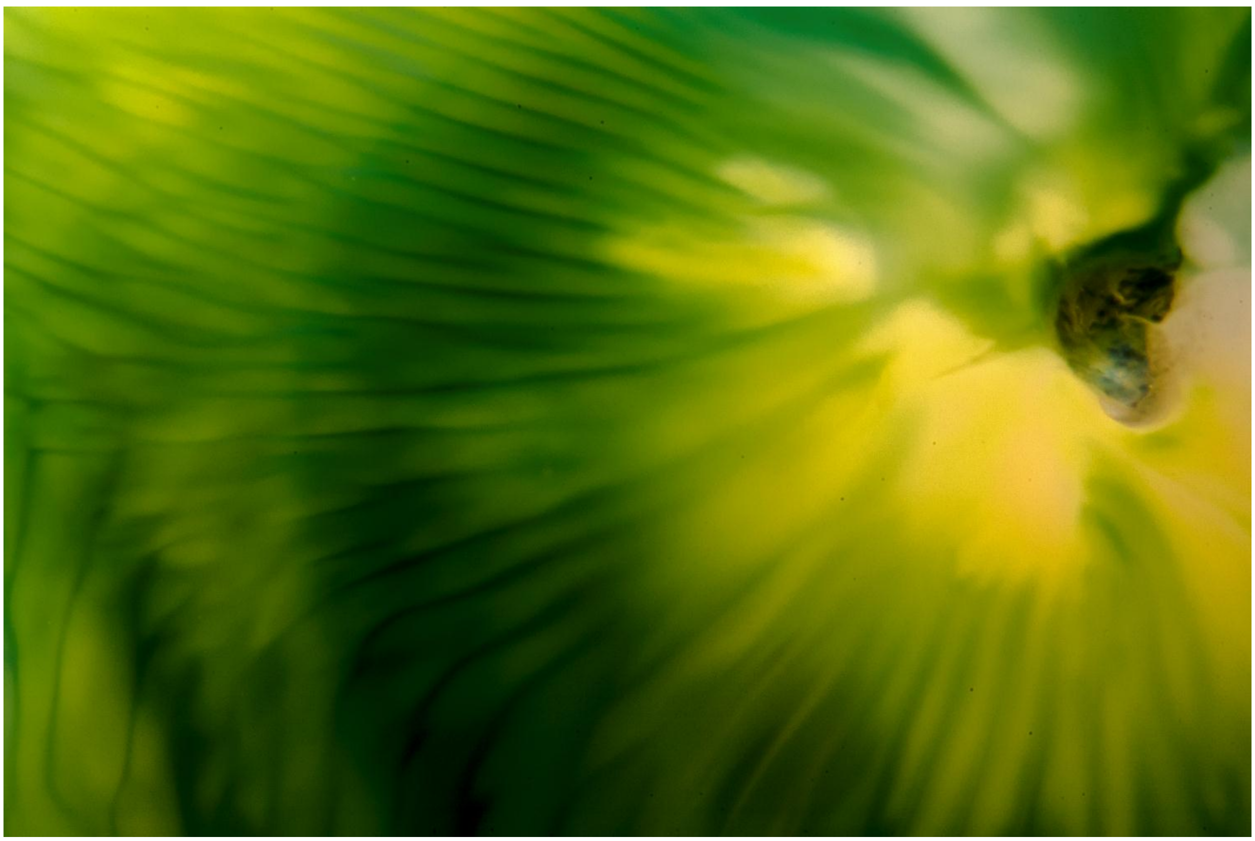

Figure 1. Final image produced with liquid dish soap, milk, and food coloring.

Students in the Flow Visualization course were given the opportunity to work in teams to create an artistic image. For this assignment, a few members of Team Zeta including myself, Mitchell Stubbs and Joshua Hect, decided to capture the aftermath of combining milk, food coloring, and liquid dish soap. The combination of these elements leads to a flowing pattern that varies in appearance every time the experiment is conducted. There are unlimited possibilities with this experiment, and the team aimed to capture a few very different images with a similar experimental set-up, which will be described below.

The experiment was performed on a glass plate, which allowed light to pass through and not reflect from nearby surfaces. The experimental setup can be seen below, in Figure 2.

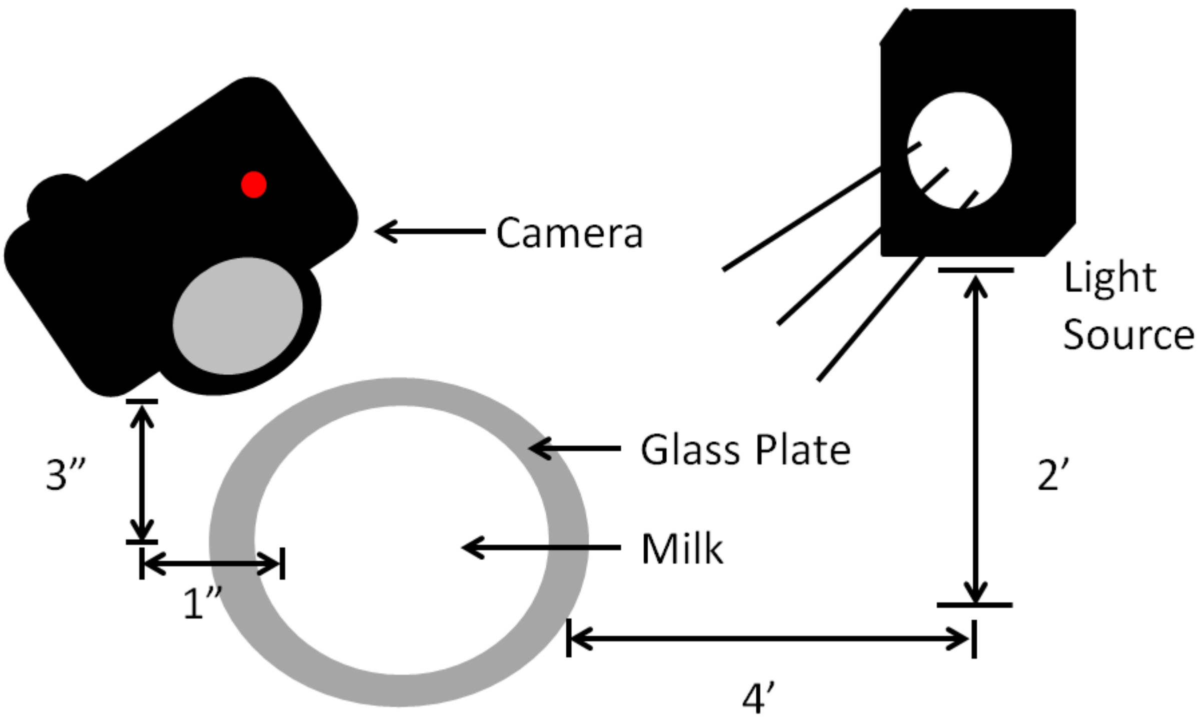

Figure 2: Experimental Setup. Vertical distances are perpendicular to the plate, and horizontal distances are parallel to the plate. The flat plane angle between the camera and light sources is 120^0. Diagram is not to scale.

As shown above, there is a thin (≅ 0.1 in) layer of milk lying relatively stagnant on the 12 in diameter plate while a few small drops of food coloring are dropped into the milk. Diffusion is minimal, and the dye and milk remain relatively stagnant until the instant the liquid dish soap (most soaps will work, however, Kroger brand dish soap was used for this experiment) is dropped onto the plate. The dish soap was dispensed directly out of the bottle to form the dark section in the upper right of the image, seen as Figure 1 on the cover page. As soon as the dish soap contacts the liquid surface, rapid movement and dispersion occurs. The dye blends with the milk, and creates the tie-dye pattern that can be seen in the image. The movement and dispersion occurs for a few minutes before the substance reaches enough of an equilibrium that visible liquid movement ceases.

Now, it is necessary to dive deeper into the reasoning behind the experiment. The dye can sit stagnant without dispersing in the milk because of the difference in densities. The 1% fat milk has a density of 62.428 lb/ft^3, while the food coloring has a slightly lower density of 62.3 lb/ft^3 (estimated as the same as water at room temperature) [1,2]. Then, the interesting part of the experiment occurs: the soap is dropped into the mix. Soap molecules have a long hydrocarbon chain, with a carboxylate head. These molecules form into a group called a micelle that can be seen in Figure 3. The carboxylate group is hydrophilic (water-loving), while the hydrocarbon chain is hydrophobic (water-fearing) [3]. When the soap interacts with the milk, the micelles form around the fat molecules, effectively attacking them with rapid acceleration that is due to the opposite polarities. This releases the surface tension of the milk, and allows the dye to expand rapidly, at an estimated 5 in/s, appearing into a tie-die pattern with rapid motion. The motion continues until the soap micelles have effectively dispersed and surrounded all fat molecules of the milk.

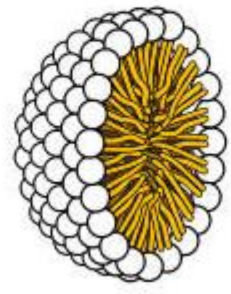

Figure 3: Soap Micelle. Carboxylate heads form the outside surface with hydrocarbon chains on the inside.

The camera used for this experiment was a Nikon D70, with an 18 – 70 mm lens. The camera settings were relatively quick to figure out, due to the aperture lock that is experienced when working with cheap extension tubes. Two extension tubes of different lengths (14 mm and 28 mm) for a total of 42 mm were used, and locked the aperture at the maximum value of 22.0. The shutter speed used for the photograph was 1/25 s, in order to create a still-shot of the moving fluid. The field of view of the lens was an estimated 3 in across. The ISO was set at 400 to amplify the small amount of light coming into the camera. A high ISO would have produced a brighter image, but sacrifices quality due to added graininess. The light source used is a 500 W work light, obtained through Greg Potts in the Durning Laboratory, in the CU Engineering Center. Adobe Lightroom 4 Beta was used to process the image. The only processing done was a custom color curve that brightened the green and yellow sections of the image.

The final image (shown in Figure 1 of the cover page) was a quick capture of the rapidly changing phenomenon. I chose to use yellow and green food coloring because I was looking for bright colors to demonstrate the effects clearly, and was pleased to later notice that the colors fit the spring weather that has been consuming Boulder recently. The soap coagulation in the upper right gives a balance to the image, and a focal center of most of the dispersion. I was satisfied with the image, but would recommend the use of a lens that has the ability to zoom in even closer, to capture the phenomenon in greater detail. This experiment could be conducted with infinite possible final results and images, and it is recommended that the user play out several trials in order to view the variability of the experiment.

Sources

1. "Density of Milk." *Hypertextbook.com*. Web. 24 Apr. 2012. <http://hypertextbook.com/facts/2002/AliciaNoelleJones.shtml>.
2. "Water - Density and Specific Weight." *Engineering ToolBox*. Web. 24 Apr. 2012. <http://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html>.
3. "How Soap Cleans." *About.com Chemistry*. Web. 24 Apr. 2012. <http://chemistry.about.com/od/cleanerchemistry/a/how-soap-cleans.htm>.