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Flow Visualization
Team Project #1
3/14/11

Team Project #1 – Food Coloring in Milk

The image taken for the first team assignment demonstrates various phenomena of food coloring mixing in milk. Whole milk was poured into a pyrex dish and a few drops of food coloring were added to the center of the dish. Then, soap was poured into the food coloring from above to quickly mix the coloring with the milk due to surface tension. Many attempts were made to capture unique patterns as the food coloring mixed with the milk, and after several hours a few good images were obtained. However, I found that more interesting patterns could be created after the mixing process had settled. When the surface tension mixing process had ended, I moved a small metal rod, approximately 3mm in diameter, through the milk to create distinct vortices. After several attempts, I stumbled upon a color combination the results in an excellent image.

The following items were acquired for the experiment:

Table 1

Food coloring dyes
Joy Lemon-Scented Dishwashing Soap
Acetone
Extra Virgin Olive Oil
Clorox Bleach
Black Background Board
Windex
2-Head Shop lamp (500 Watt/110 V/ 60Hz)
Liquid Glycerin
8 Inch Diameter Pyrex Dish
Stir Rod

The 8 inch diameter, glass Pyrex dish was used to contain the milk. This dish was placed on a black backdrop to create a clean, featureless backdrop. The shop lamp was initially placed about two feet away from the rest of the set-up, as shown in Figure 1, but was experimented with until the lighting was ideal. Aesthetically, no positioning of the shop lamp seemed as nice as the ambient light, so it was eventually taken out of the setup for the submitted image. For my purposes, it was not used, but some images did utilize the shop lamp. Photos were taken from several different angles, but the best ones were taken from directly above at a distance of approximately 10 inches and stabilized using a tripod and burst setting on the camera. The burst setting allowed for the camera operator to step away from

the camera while the photographs were taken, thus stabilizing the camera by removing the motion induced by pushing the shutter button.

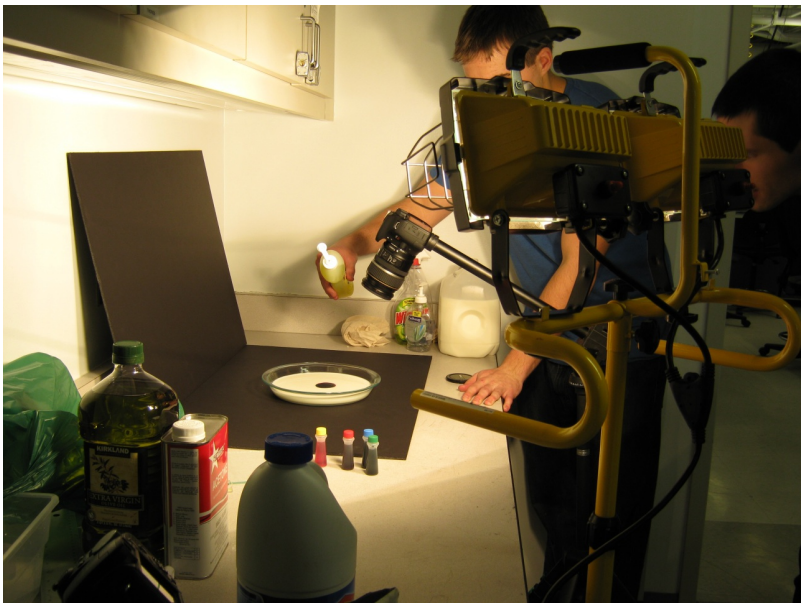

Figure 1 – Laboratory Set-Up

The setup of the experiment was to add food dyes in various amounts, combinations, and configurations to the surface of the milk and/or various amounts of olive oil, and to drop liquid glycerine, soap, acetone, Windex, and bleach into it. This was to explore which surfactants would have the most interesting effects on subject liquids. After many trials with varying levels of success, it was determined that the milk, dish soap, and food dyes were most effective in producing and interesting and noteworthy outcomes. The stir rod was used to induce flow in some cases as well. Additionally, variations in the amount of time that the food coloring was given to diffuse into the milk on its own were experimented with. Figure 2 below shows the dimensions of the pryex dish with milk.

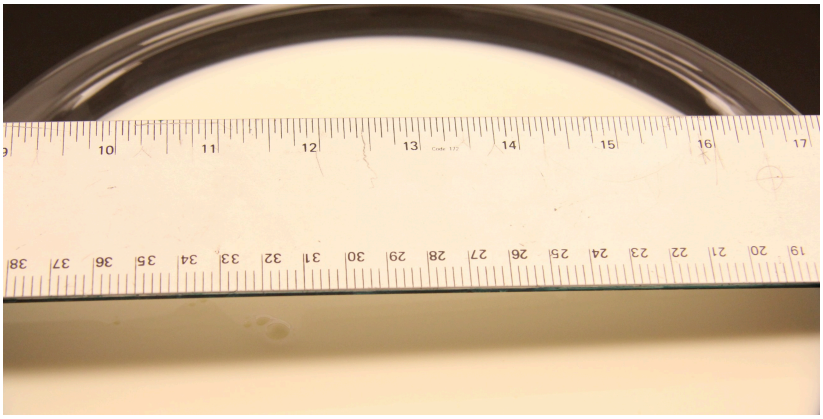

Figure 2: Milk Pan Dimensions

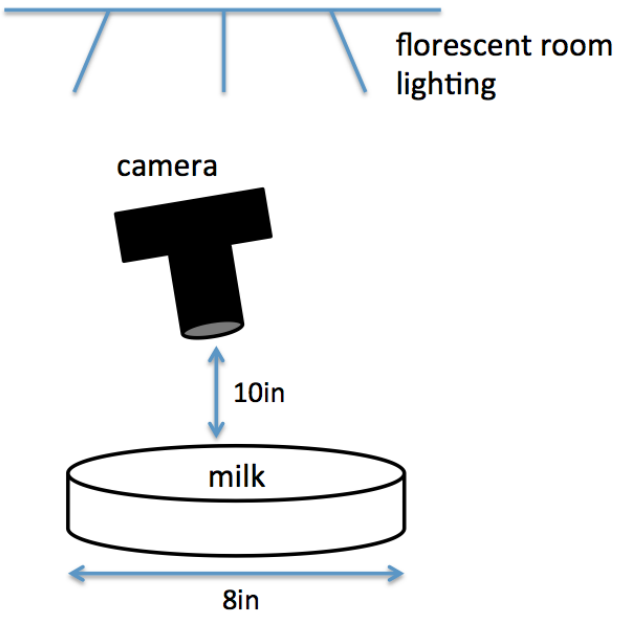

Figure 3: Flow Visualization Apparatus

Figure 3 shows the various dimensions of the experimental setup. Please note that team member Gary Velasquez wrote the experimental setup description on the previous page.

The composition of milk is mostly water but contains vitamins, minerals, proteins, and small particles of fat suspended in solution. Whole milk will simply have less water and more compounds than skim milk, which is intentionally watered down. The important components of milk that pertain to this experiment are the fats and proteins, which are extremely sensitive to changes in the surrounding solution, or milk. The addition of dish soap alters the chemical bonds that hold the proteins in suspension causing them to rapidly, and semi-chaotically, spread throughout. The food coloring is along for the ride; as the proteins move the coloring droplets are drug along allowing the path of the proteins to be visible. After the initial drop of soap is added it forms a micelle, or a cluster of soap molecules. This cluster has a special structure that allows it to "grab" fat molecules. Figure 4 shows a typical micelle.[3]

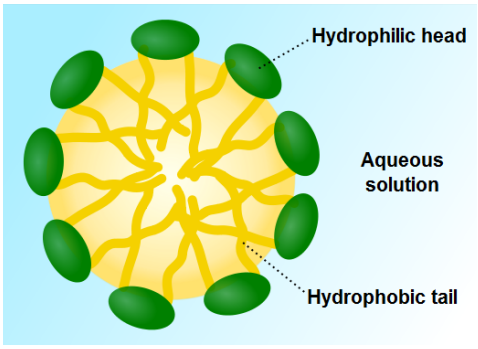

Figure 4: Simple diagram of a micelle.[3]

The tails of the soap molecule are hydrophobic, forcing them inward and away from water, and lipophilic, which causes the tails to secure a fat molecule. The result is a fat molecule surrounded by soap molecules. As time passes, the micelle will distribute itself around the milk until both the soap and fat are evenly distributed. Once distributed, the motion in the milk will stop leaving a display of randomized wonder.

Another cause for the explosion of color is the change in surface tension. Since milk is primarily water, its surface will behave as such. This can be seen when the food coloring is first added and the droplets sit near the surface with minimal spreading. Dish soap is a surfactant that will change the surface properties of the milk, or water. In this case the soap reduces the surface tension by dissolving fat molecules allowing the rapid mixing as described above. Please note that the above description of the soap/milk interaction was written by team member Andrew Beat.

After the soap and milk interaction settled, a metal rod was moved through the milk to create von Karman vortices. First, the Reynolds number of the flow is given by Equation 1 with a characteristic length equal to the diameter of the metal rod. The velocity was determined by estimating the amount of time it took to move the metal rod across the entire milk pan, about 20 cm in one second. With a low Reynolds number of 531, the flow will be laminar, as seen by the laminar von Karman vortices in the final image.

$$Re = \frac{VL}{\upsilon} = \frac{(.2)(.003)}{1.13\times10^{-6}} = 531 \qquad (1)$$

From reference 1, the von Karman vortices are created at Reynolds numbers above ~48. Figure 5 shows the von Karman vortices and how different flow modes change the periodicity of the vortex shedding in the wake of a cyclinder.[1]

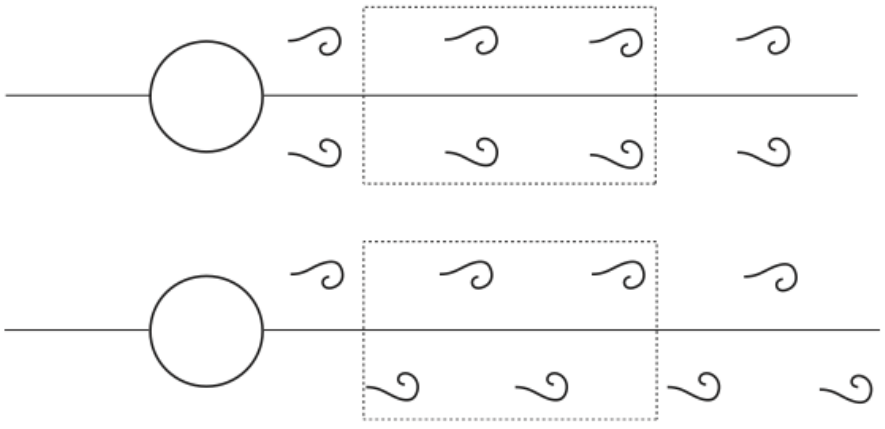

Figure 5: von Karman vortices in the wake of a cyclinder.[1]

To produce the final image, milk was added to the pyrex dish to a depth of ~1in. Then, a total of 8 drops of red, green, blue, and yellow food coloring were added to the center of the milk. A few seconds later, about 1 teaspoon of common dish soap was poured into the food coloring and milk from above. After the surface tension reaction settled, about 30 seconds later, a metal rod was moved across the milk dish to create the vortices seen in the final image. The lighting setup for the final image is shown in Figure 3. Preliminary images taken with the floodlights shown in Figure 1 resulted in an ugly yellow hue, so they were eventually removed and we only used the florescent overhead lights in the room.

The image field of view was approximately 6in in width and 4in in height, and the distance from the camera lens was ~10in. A Canon T2i digital camera with a 17-85mm focal length lens was used to take the picture. The camera was in burst mode, taking 10 images continuously at 3.7 frames/second.

Camera:	Canon T2i DSLR
Focal Length:	61mm
ISO:	ISO 800
Shutter Speed:	1/80 s
Aperture:	*f*/5.6
Original Pixel Size:	5184 x 3456
Final Pixel Size:	5184 x 3456

Photoshop was used to slightly modify the original image. The original was a bit dark, so the brightness was increased along with the exposure setting. Then, the contrast was slightly increased to compensate for the increase in brightness. No other modifications were made of any kind.

Overall, I was very pleased with the final image. After hours of attempting to take images from a tripod, I found that experimenting with the camera in hand lead to the most interesting images. Also, I found that mixing the milk with a small rod lead to the interesting vortices seen in my final image. After the first few projects, I'm beginning to think that my best work comes from a more creative style rather than trying to setup a specific phenomenon.

References

[1]Mureithi, Njuki W., K. Huynh, M. Rodriguez, and A. Pham. "A Simple Low Order Model of the Forced Karman Wake." *International Journal of Mechanical Sciences* 52 (2010): 1522-534. Print.

[2]Spangler, Steve. "Color Changing Milk." *Science Projects Experiments, Educational Toys & Science Toys*. Web. 14 Mar. 2011. <http://www.stevespanglerscience.com/experiment/00000066>.

[3]"Surfactant." *Wikipedia*. Web. 14 Mar. 2011. <http://en.wikipedia.org/wiki/Surfactant>.