Flow Visualization

Group Image 1

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Introduction

Flow Visualization is the study of fluid flow mechanics through photographic art. The image above, selected for the Group Image #1 assignment, could easily be mistaken for an abstract painting of some sort. However, this is actually an image of a beautiful mixture of food colorings which have been curiously blended in such a way through the reaction of whole milk and dish soap. In our simple experiment, we filled a shallow dish with milk, added numerous droplets of red, blue, green and yellow food coloring dyes to the center, and placed a droplet of dishwashing soap into the center of the food coloring. The soap reacts with the fat molecules in the milk and causes them to spread rapidly. The food coloring stays attached to the fat molecules and moves with them, and with the addition of some slight perturbation from a metal stirring rod, I was able to capture the image above.

Procedure

The following ingredients/items were acquired for the experiment:

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
9 Inch Diameter Pyrex Dish
Stir Rod

Table 1: Experiment Equipment

The 9 inch diameter, glass Pyrex dish was used to contain the milk. This dish was placed upon a table on top of the black background 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 set-up. 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 12 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 by removing the motion induced by a person pushing the button.

Figure 1: Experimental Setup

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 additional 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.

My specific image was taken on March 3, 2011 with a Canon EOS REBEL T2i camera. The data for the finalized image is shown in Table 2 below. There was also additional photo editing using *Adobe Photoshop CS5,* mostly to adjust the contrast to bring out the pinks and blues more.

Shutter Speed	1/100 sec
F-Stop	f/5.6
Max Aperture Value	f/5.7
ISO Speed Ratings	800
Focal Length	73.0 mm
Pixel Resolution (Post-crop)	3312 x 5046

Table 2: Photo Info

Analysis

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. Food coloring is less dense than the milk itself, so it remains suspended within the fat molecules of the milk. As the molecules spread from the reaction, the food coloring is taken along for the ride.

After the initial drop of soap is added it forms a micelle, or a cluster of soap molecules. This cluster has a special structure which allows it to “grab” fat molecules. Figure 2 shows a typical micelle.

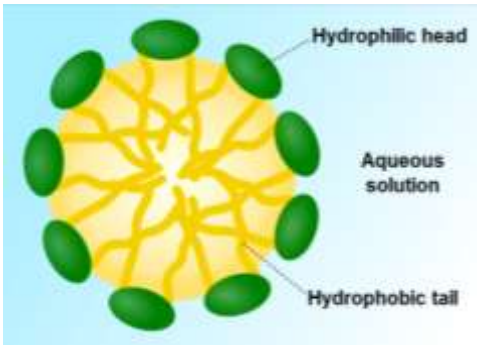

Figure 2: Simple diagram of a micelle

The tails of the soap molecule are hydrophobic (repelled by water), forcing them inward and away from water, and lipophilic, which causes the tails to secure a fat molecule. The hydrophilic (attracted by water) components of the soap point outward, forming the outer surface of the micelle. 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 which 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.

The other interesting component of this image is the colorful vortices that are primarily in the upper right corner of the image. These were induced by moving a metal stirring rod across the solution. The rod is an obstruction to the fluid flow, and there is a boundary layer of slower moving liquid around and behind the rod. This creates a shear flow layer which causes vorticity as the fluid moving around the rod has greater velocity than that directly behind it. In our case, the moving rod generated a high enough Reynolds number to create a Karman vortex street, where vortices (or "eddies") are generated in the wake of the stream and spin in alternating opposite directions. A simple diagram of this effect can be seen in Figure 3. This effect can be seen clearly immediately after using the stirring rod, but because of the chaotic and continuous nature of the soap reaction, the mixture is continuously moving and causes the vortices to move along with it.

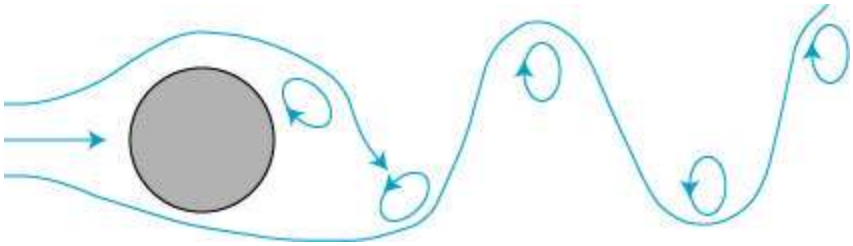

Figure 3: Karman votex street

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