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MCEN 4151: Flow Visualization
21 September 2016

Get Wet 2016 Report

Image Context

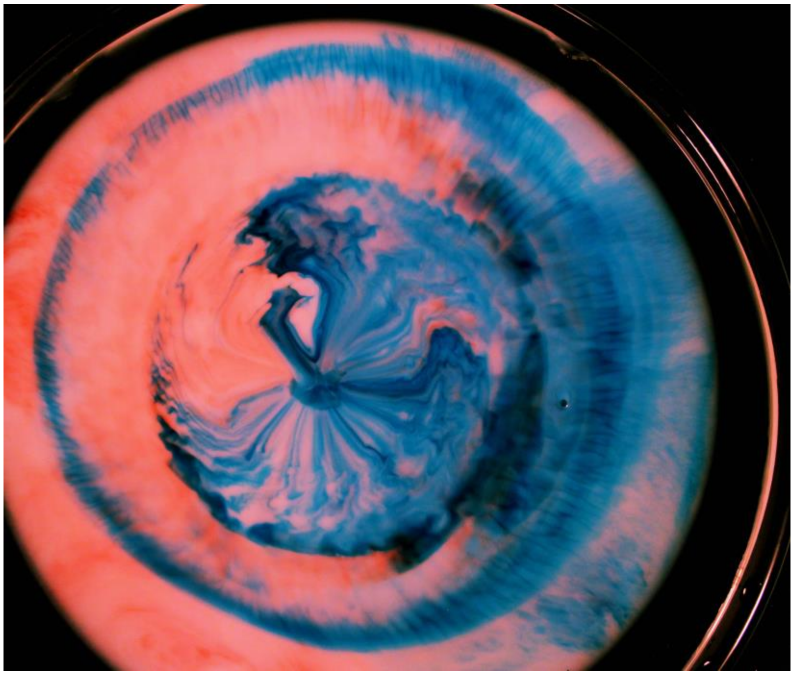

Figure 1: Get Wet 2016 Final Image

The image seen in Figure 1 was created while playing with food dye to try and capture various fluid movements. Originally my intent was to drop the fluid in a glass of swirling water to observe how the dye mixed around the glass while also sinking. This proved much harder than initially anticipated due to the observed similarity in the density of water and dye and as such difficult capture of the dye mixing in a spiral as envisioned. From here other fluids were investigated and milk proved to be the most interesting using an experiment mentioned in class that caught my attention. By mixing milk, food coloring, and dish soap, I sought out to observe the Marangoni Effect of varying surface tensions.

Flow Apparatus

The capture of this experiment is explained later on under the section for Visualization Technique. It was a simple setup with a stationary plate in which to observe the fluid. 2% milk was used since it was readily available and has a moderate fat content. The fat content of the milk used can affect the rate at which the reaction occurs and duration of the reaction. This is due to the interaction between the soap droplet and the fat molecules in the milk. It is commonly known that dish soap is useful to remove grease and grime. Soap molecules are attracted to the fat molecules in the milk and surround them to create a stable micelle (Doherty, 2003). The number of fat cells present will thus affect how long it takes for the soap to react with all the fat cells and equally how fast they can react due to the increased concentration. As such, 2% provided a good medium under which the experiment could be steadily visualized.

Now that it is understood why the soap reacts with the milk, it is necessary to understand why it makes the dye move, centered around the soap droplet, as is evident in Figure 1. The phenomenon known as the Marangoni effect describes the convection of the milk-soap interface. Soap has a surface tension lower than that of milk, so when a droplet of soap was dropped from a spoon over the plate, the droplet of soap disturbed the uniform surface tension of the milk in the plate. Since surface tension is the result of molecular forces pulling on neighboring molecules, the decreased surface tension near the soap droplet lets the milk molecules further out pull harder on the molecules towards the center (Sharp, 2014). This results in the milk accelerating outwards, away from the soap droplet, visualized by the dye as it is carried with the milk. A short duration of this experiment will merely witness the dye spreading outwards, but as the reaction is further observed, the dye begins to recirculate. This is due to convection necessary for the soap molecules to continue to spread out in search of other fat molecules—as the molecules in movement along the surface reach the edge of the plate they have nowhere to go but down and recirculate towards the soap bubble. The collage shown in Figure 2 shows raw images of how the dye progressed over time (about 30 seconds) taken at random intervals to capture interesting patterns throughout the process.

Of interest is that the blue dye moved faster than the red dye and in the end was more prevalent on the surface of the milk with a concentric ring moving outwards from the soap bubble. This occurrence was likely started by the soap droplet being slightly closer to the blue dye droplet than the red, so the blue dye was impacted sooner by the decrease in surface tension and thus reached the edge of the plate quicker to begin the recirculation process. Beyond that, the slight differences between red and blue food coloring, FD&C Red 40 and FD&C Blue 1, respectively, could be the point of further investigation. The location and bonding of the nitrogen atoms in red and blue are different which may play some factor. Additionally, the red dye contains a hydroxyl group which could lower the red dye's surface tension. Related to the OH^- found in alcohol, which is commonly known to have a low surface tension, this hydroxyl group could cause the red dye to be less effected by the lower surface tension of the soap than the blue dye—thus the reason why the blue exhibits greater movement during the reaction. Shown in Figure 3 and Figure 4 are the structures for red and blue food dye (University).

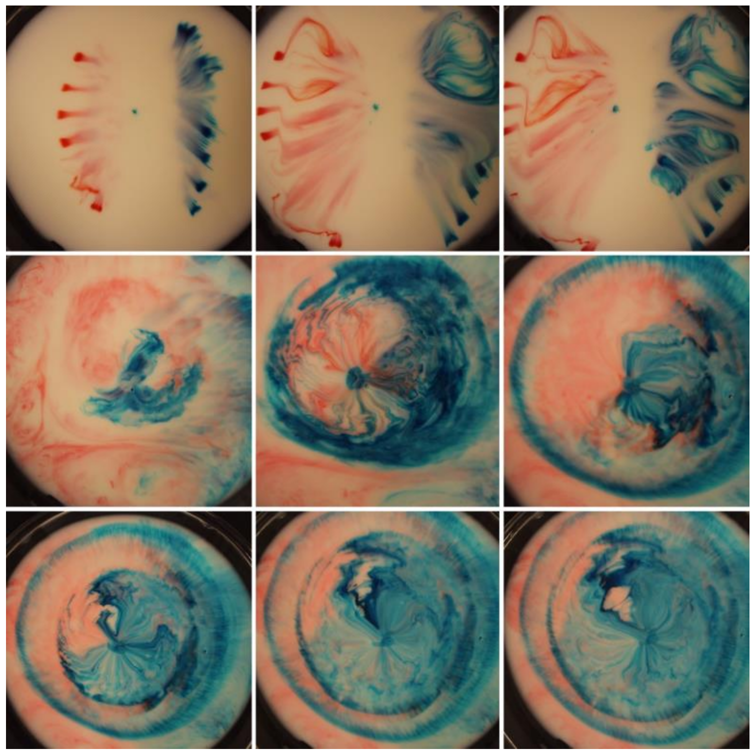

Figure 2: Collage of Dye Progression

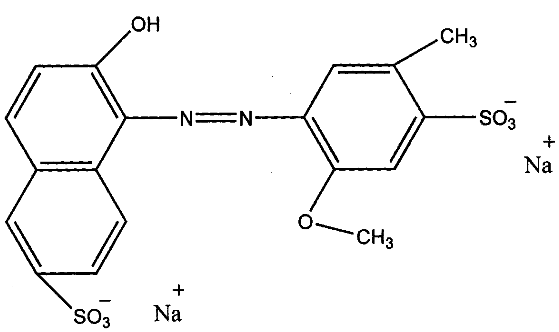

Figure 3: FD&C Red 40 Structure

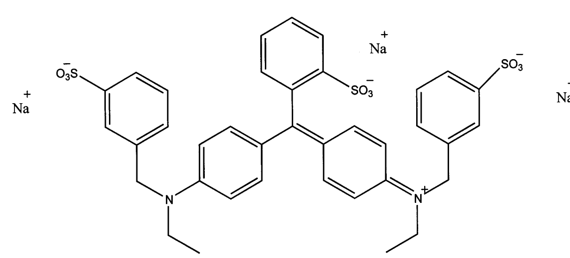

Figure 4: FD&C Blue 1 Structure

Visualization Technique

For the visualization of this phenomena resulting in the final image, I used a rather simple indoor setup. It involved a glass plate on a black table to create a background in which the lighter colored milk and dye could stand out. The blue and red dye were used to observe how the surface tension gradient would affect the movement of the milk molecules. Lighting from an LED flashlight on the side provided additional lighting from the ambient light to help illuminate the milk. It also aided in the reflection seen on the rim of the glass plate. The camera was held directly over the plate to capture the image as discussed in the following section.

Photographic Technique

To capture this photo, a Canon Rebel T3i was used in manual mode. The camera was hand held close to 1ft over the plate with a focal length of 20mm in order to cover a field of view around 1ft as well. The aperture was set to f/3.5 with ISO of 800 and shutter speed of 1/30 sec in order to let in the proper amount of light for image to turn out right. If more external light had been applied the ISO could have been decreased or shutter speed increased, but the lights would have provided unwarranted reflection. The chosen settings were able to achieve the desired picture outcome. The camera produced a raw image with dimensions of 5184x3456 pixels, and after post-processing in Adobe Photoshop, it was reduced to 4036x3424 pixels. This cropping removed the distracting background around the edges and focused the viewer on the fluid flow. Some of the plate was kept for the artistic affect that the reflection on the glass creates. In Photoshop, the image was edited to first set the black value to that of the dark background around the upper left corner. This reduced any slight distractions from the dark table. Next, the red, blue and green curves were independently according to Figure 5. Next the blue and red curves were edited further in a separate curves window as seen in Figure 6 to achieve the final image highlighting the red and blue dye used in the photo. A side-by-side of the unedited and final photo are shown in Figure 7 and Figure 8, respectively.

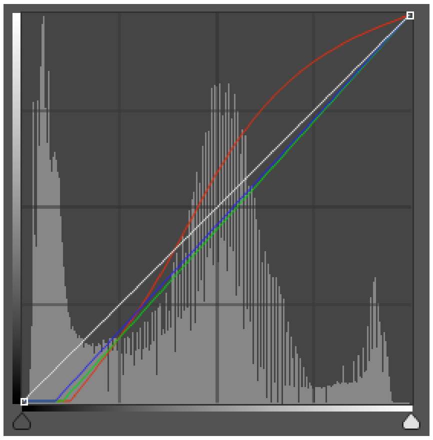

Figure 5: Curves 1

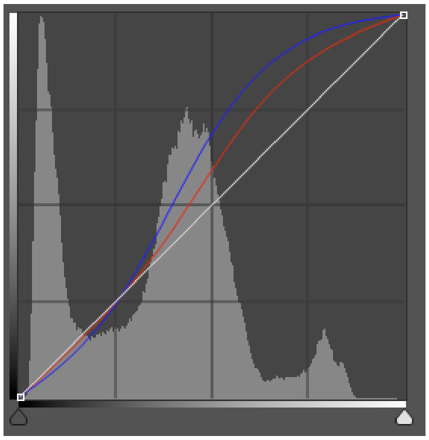

Figure 6: Curves 2

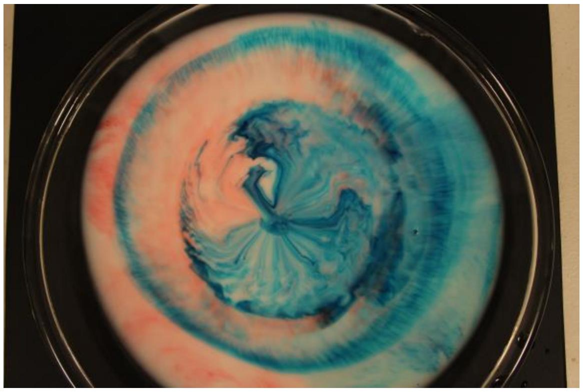

Figure 7: Unedited Photo

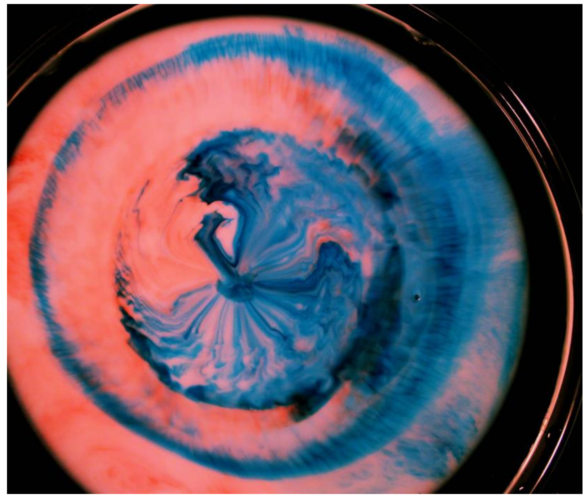

Figure 8: Final Image

Conclusion

In the end, this image reveals a great representation of the Marangoni Effect over the course of the interaction of soap and milk. The final image shows how the surface tension gradient creates movement from the lowest surface tension to greater surface tension. The final image is also pleasing to look at since it can't help but resemble an eye the way the blue ring radiates outward. Still, the presence and greater groupings of blue dye leads to questions on why that is the case? To improve the understanding, it would be great to have a stationary camera to take pictures at equal intervals which would help to observe the rate at which each dye and the interaction as a whole move throughout the interaction. To develop this experiment further, the reaction could be observed until it stops with all the fat molecules taken at which point the final position of the dyes could be recorded. Individually testing each dye color would be another option to observe their behavior independently. All in all, the final image provides a great blend between the visualization of a fluid phenomenon and artistic touch.

References

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