MCEN 4151: Flow Visualization
September 22, 2015
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Flow Visualization 1st Assignment: Get Wet

Purpose:

The motivation behind this image was to acquire a clear and well-defined photograph of a fluid flow for the first flow visualization assignment. After watching numerous fluid demonstrations of marangoni fluid flows on the web it was decided that the phenomenon would be intriguing to capture. In order to clearly be able to visualize this fluid flow milk and food coloring were used to model the flow for the contrast between the two fluids. This report will describe the experimental set up used to take the image and the fluid physics that created the image.

Flow Apparatus:

An 8x8 inch square baking dish was filled with one cup of whole milk and placed on a counter (figure 1). 6 drops of food coloring were added to the baking dish, 1 drop of blue, 1 drop of green, and 4 drops of red. The blue food coloring was placed in the center of the dish and allowed to bleed into the milk for about 15 seconds. Then a drop of green food coloring was added to the center of the blue ring and 4 drops of red were evenly placed around the blue food coloring, see figure 2. Next a Q-Tip dipped in dish soap was placed in the center of the green and blue dye circle for about six seconds causing the dye to spread. After the milk had settled another Q-Tip dipped in dish soap was placed in the top red dye circle for about four seconds. After the milk had settled the image was taken.

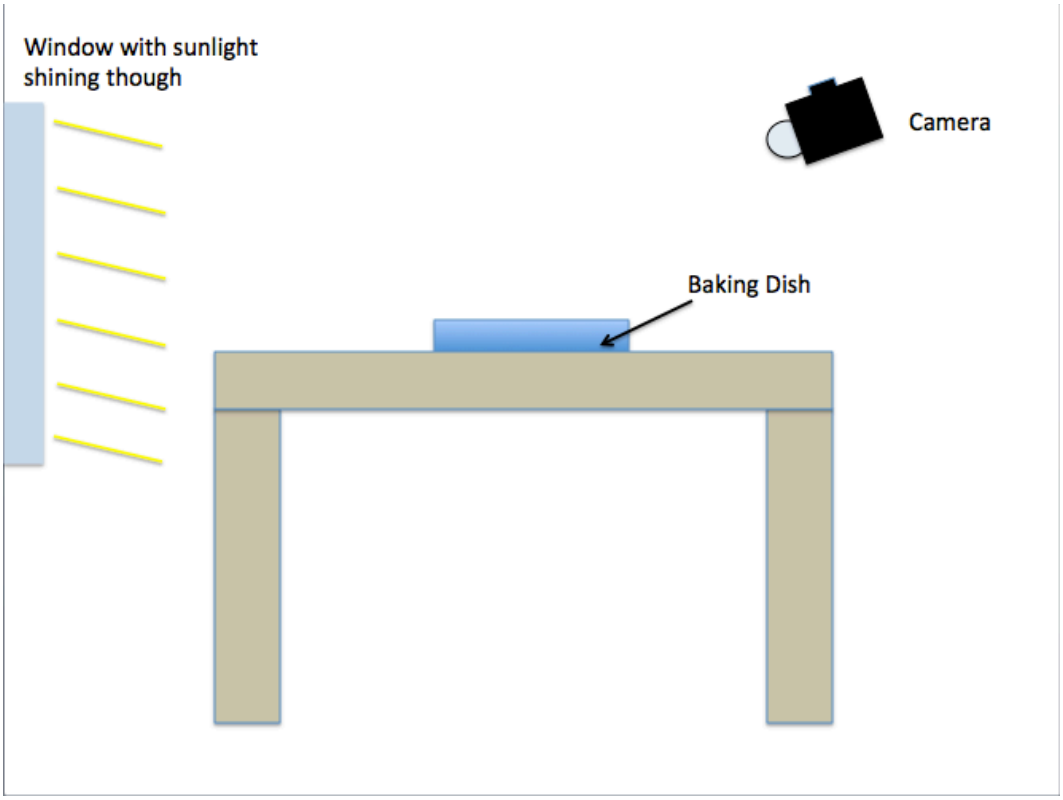

Figure 1: Flow Apparatus Set Up

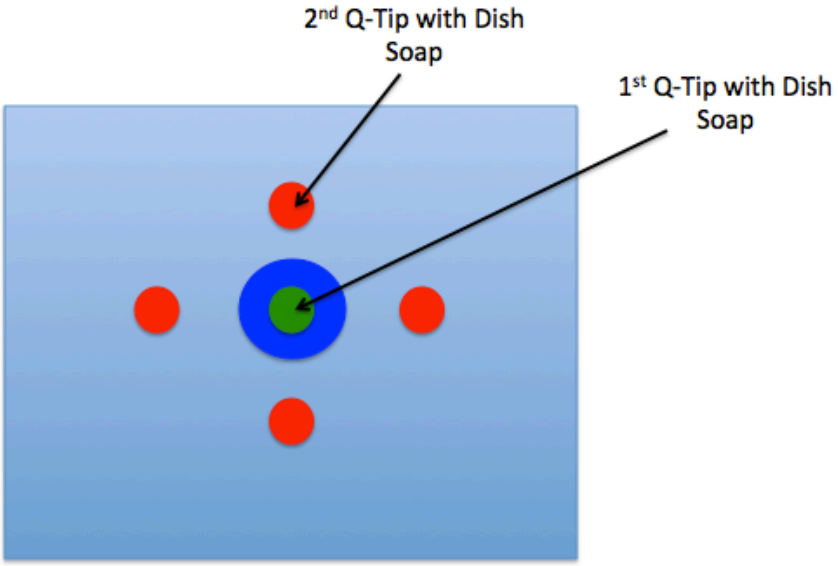

Figure 2: Diagram of Food Dye and Milk Set Up

Flow Dynamics:

The fluid motion shown in this demonstration is caused by what is known as the marangoni fluid flow. The marangoni flow is a fluid flow that is created when a liquid with a higher surface tension pulls a fluid of lower surface tension towards the higher surface tension[1]. This gradient in the surface tension in this experiment is caused by the addition of a bipolar substance (dish soap) into the milk.

Whole milk is comprised mainly of water with a combination of proteins, fats, vitamins, and minerals suspended in the solution. Water molecules exert a force similar to a magnet where one side of the molecule attracts and the other side repels. When a water molecule is surrounded by like molecules the molecule exerts an equal force from both sides; it attracts the molecules on one side with the same force that it repels the molecules on the other side[2]. The same situation applies to the water molecules in the milk solution. The water molecules at the surface on the other hand are not surrounded by water molecules, but are in contact with air on one side. This causes the water molecules to become more "attracted" to the water molecules below it. Basically the water molecules below the surface pull the surface molecules down causing a film to form on the surface. This is known as surface tension and the force between the water molecules is known as the cohesion force[3].

Household dish soap has bipolar characteristics, which implies that the soap molecules have two poles, one that is nonpolar and one that is polar. What this means is that one end is hydrophilic (water loving) and the other end is hydrophobic (water fearing). When a bipolar substance is introduced into water it

weakens the bonds holding the water molecules to each other. In this experiment when the hydrophilic portion of the soap dissolves in the water it weakens not only the bonds between the water molecules, but also the bonds between the water molecules and the fats and proteins in the milk. As the hydrophilic potion of the soap dissolves the hydrophobic portion of the soap grabs on to any non-water molecule that happens to be in the solution, in this case it grabs onto the fat and protein molecules in the solution[2]. Since the hydrophobic molecules want nothing to do with water they attempt to roll way from any water in the solution dragging the fat and protein molecules with them. This causes the protein and fats to flow away from the Q-Tip, which causes a gradient in the surface tension of the solution, with a low surface tension around the Q-Tip and a higher surface tension far way from the Q-Tip. The higher surface tension portion of the solution pulls the lower surface tension solution towards the point of highest surface tension and the milk and food coloring are seen to flow away from the Q-Tip. The force causing the low surface tension to be drawn towards the higher surface tension is called the marangoni force and the resulting flow is a marangoni flow.

Visualization Techniques:

Materials

- Safeway Brand Food Coloring (Safeway)
- 1 Cup Whole Milk
- 1 8x8 Glass Baking Dish
- 2 Q-Tips
- Household Dish Soap (Method Brand)

Using the setup described above this experiment can be replicated. This image was taken in the late afternoon around 2:30pm on September 13, 2015. The natural sunlight filtering in though the kitchen window was used as the lighting source for this image. Without the use of food coloring to help highlight the marangoni flow this phenomenon would be very difficult to visualize.

Imaging Technique:

Table 1: Image Specifications

Focal Length	Exposure	f/	ISO
100.0 mm	1/125 sec	5.6	6400

Camera Model: Canon EOS REBEL SL1
Image Size: 5184 x 3456
Resolution: 240 Pixel Per Inch

The post processing preformed on the image included manipulating the color curves and using the clone stamp. The color curves were tweaked until a bight white background was achieved without losing information within the fluid flow. The blue and green color curves were also manipulated to create a more distinct boundary

between the fluid flows. The clone stamp tool was used to remove the edge of the baking dish that could be seen in the upper left corner of the image. No cropping was used.

In future tests the image should be taken directly after the fluid has moved to reduce the dye bleeding into the milk. A tripod might also be a good addition to the set up to insure no accidental motion blur from a shaking camera.

Image Revelations:

This image captures the beautiful and fascinating ways a water solution reacts to the introduction of a bipolar substance. In creating this image not only was a clear demonstration of a marangoni flow created, but a visually interesting image as well.

Works Cited

"Multiphysics Cyclopedia." *What Is the Marangoni Effect?* COMSOL, n.d. Web. 24 Sept. 2015. <https://www.comsol.com/multiphysics/marangoni-effect>.

Nave, R. "Surface Tension." *Hyperphysics*. Hyperphysics, n.d. Web. 24 Sept. 2015. <http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html>.

Science Buddies. "Surfactant Science: Make a Milk Rainbow." *Scientific American*. Scientific American, 13 Mar. 2013. Web. 24 Sept. 2015. <http://www.scientificamerican.com/article/surfactant-science-make-a-milk-rainbow/>.

Image Assessment Form
Flow Visualization
Fall 2015

Name(s) Kelsea Anderson

Assignment: Get Wet Date: September 22, 2015
Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Comments
Intent was realized	√	
Effective	√	
Impact	√	
Interesting	√	
Beautiful	√	
Dramatic	√	
Feel/texture	√	
No distracting elements	√	
Framing/cropping enhances image	√	

Flow	Your assessment	Comments
Clearly illustrates phenomena	√	
Flow is understandable	~	
Physics revealed	√	
Details visible	√	
Flow is reproducible	√	
Flow is controlled	√	
Creative flow or technique	~	
Publishable quality	X	

Photographic/video technique	Your assessment	Comments
Exposure: highlights detailed	√	
Exposure: shadows detailed	√	
Full contrast range	√	
Focus	√	
Depth of field	√	
Time resolved	√	
Spatially resolved	√	
Photoshop/ post-processing enhances intent	√	
Photoshop/ post-processing does not decrease important information	√	

Report		Your assessment	Comments
Collaborators acknowledged		√	
Describes intent	Artistic	~	
	Scientific	X	
Describes fluid phenomena		X	
Estimates appropriate scales	Reynolds number etc.	X	
Calculation of time resolution etc.	How far did flow move during exposure?	NA	
References:	Web level	~	
	Refereed journal level	NA	
Clearly written			
Information is organized		~	
Good spelling and grammar		~	
Professional language (publishable)		X	
Provides information needed for reproducing flow	Fluid data, flow rates	~	
	geometry	~	
	timing	~	
Provides information needed for reproducing vis technique	Method	~	
	dilution	~	
	injection speed	~	
	settings	√	
lighting type	(strobe/tungsten, watts, number)	NA	
	light position, distance	~	
Provides information for reproducing image	Camera type and model	√	
	Camera-subject distance	X	
	Field of view	√	
	Focal length	√	
	aperture	√	
	shutter speed	√	
	Frame rate, playback rate	√	
	ISO setting	√	
	# pixels (width X ht)	√	
	Photoshop and post-processing techniques	√	
	"before" Photoshop image	√	