MCEN 5151: Flow Visualization

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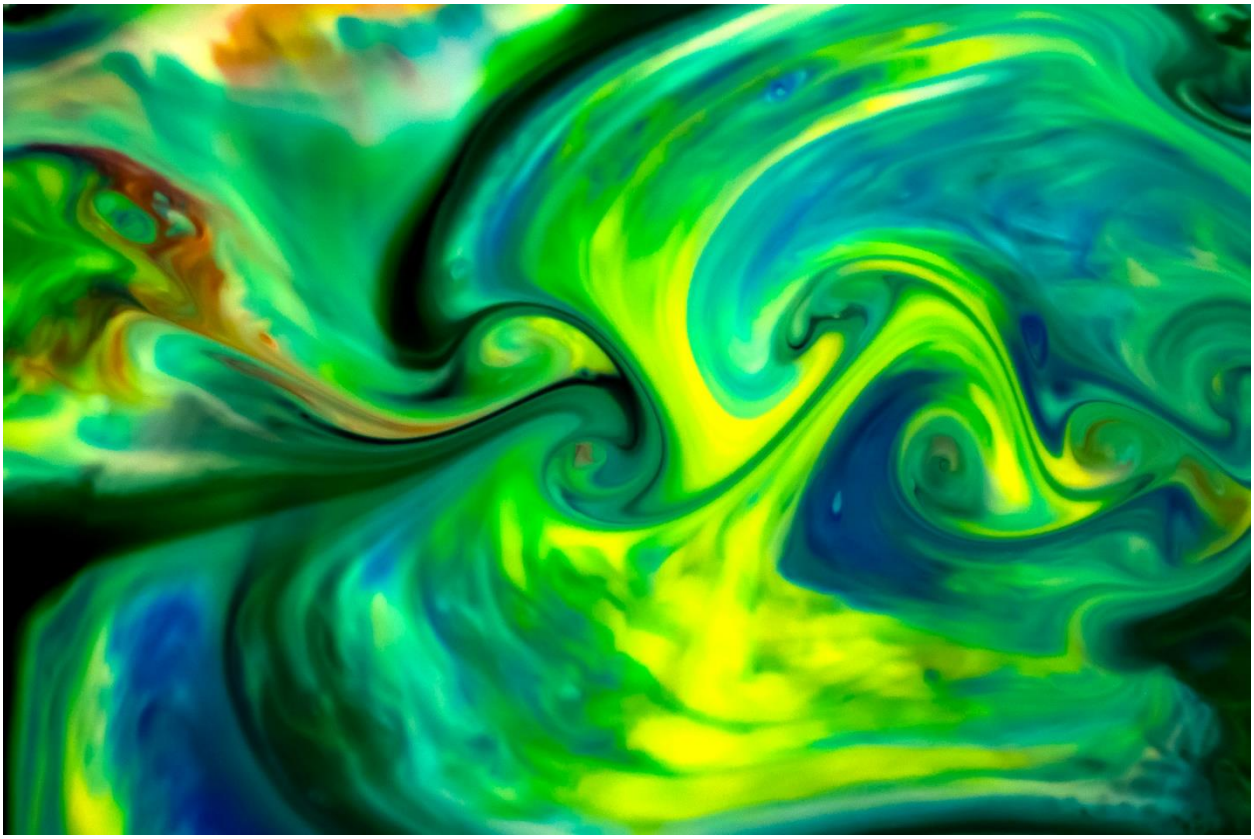


Flow Visualization 1st Assignment: Get Wet

Purpose

The motivation for this image was to try to capture a cool image from an at home fluids experiment that I had never done before. I had seen videos on YouTube of people creating cool flows using milk, food coloring and dish soap. It seemed like an experiment that required minimal supplies and skill and it would be tenable to take an interesting picture. The report attempts to describe how this picture could be recreated.

Visualization Techniques:

Materials:

- Kroger vitamin D milk
- Kroger neon food coloring
- Dawn dish soap
- Q-tips
- White dinner plate from target

The image was creating using the imaging technique and flow setup outlined below.

Imaging Technique:

Camera: Nikon Z6

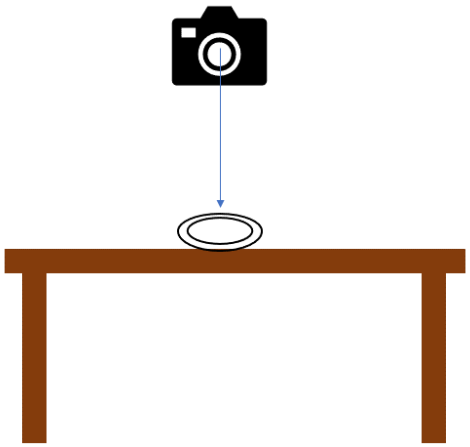
Image Size: 5184 x 1363

Focal Length	Exposure	f/	ISO
69 mm	1/60	4	3200

I have limited experience with both photography and post processing. To take the picture I held the camera by hand. Since the shutter speed was relatively fast this mean I could get a clear image. I considered using a tripod but determined that it would be difficult to set up and wouldn't greatly improve the images. After the photo was taken, I wanted to increase the brightness and contrast in the image. I had some success in achieving this by playing with the RGB curve using darktable editing software.

Flow Apparatus:

The image was taken inside with the source of light coming from a ceiling light (an incandescent light bulb). Whole milk was poured onto a regular white dinner plate to a depth of about half a centimeter in depth. Then about ten drops of neon green food coloring and ten drops of neon blue food coloring were dropped around the plate (dispersed evenly). Next, a q-tip was dipped in dish soap and then into the milk on the plate. At this point the food coloring spread around considerably. To achieve more interesting results, the q-tip was moved around while still dipped in the milk. The q-tip was removed, and photos were taken while the flow became stagnant. The camera was held 6-12 inches above the surface. This was repeated many times to obtain as many different flow images as possible.



Flow Dynamics:

The phenomenon demonstrated in the image is called the Maragoni effect. Essentially this means two fluids of varied surface tension interact with each other. The result is a gradient of surface tension and induces motion in the milk[1].

$$[\mu(\nabla u + (\nabla u)^T] \cdot n = \gamma \nabla_t T^2$$

Equation 2 above describes the dynamics of flow as a function of dynamic viscosity **μ**, thermal dependence on surface tension $\boldsymbol{\gamma}$, temperature T and the normal direction to surface n. Here u is the velocity vector. The soap lowers the local surface tension of the milk. The higher surface tension in the milk outward pulls the milk local to the soap outward. The differences in chemical properties/structures for milk and soap provide more insight as to why soap lowers the local surface tension of milk. Soap molecules have hydrophilic heads and hydrophobic tails. Consequently, soap pushes local water molecules farther away from each other and lowers the surface tension[3]. Food dye of different colors enables this phenomenon to be better visualized.

Reynolds Number:

$$Re = \frac{\rho v l}{\mu} \approx 0.05$$

Where **ρ** is density, v is velocity, l is a characteristic length scale, and **μ** is the dynamic viscosity. The properties of milk are listed below[4]

$\rho = 1030$ kg/m^3 (milk)

$v =$ ~0.01 m/s (approximate velocity of milk and food coloring)

$l =$ ~0.01 m (roughly the small area around a q-tip head)

$\mu = 2$ cp

This gives an approximate Reynolds number of 0.05. The Reynolds number is effectively the ratio of inertial and viscous effects. At these low speeds and small length scales the flow is essentially dominated by the viscous effects. This means the flow would be in the laminar flow regime. The photograph shows distinct lines separating the food coloring. The final image I chose actually looks similar to a von Karman vortex street. A von Karman vortex street is considered a type of laminar flow downstream of a blunt body.

Results of Final Image and Revelations:

I was happy with the results of this image. I think the choice of colors worked out well: they were bright and contrasted will with each other, but they were not too aggressive either. I really like the pattern that I was able to capture. As sated previously it reminds

me of a von Karman vortex street, even though this flow has nothing to do with a von Karman vortex street. While I was editing the photo, I wanted to make sure my final image did not end up being too doctored, while still making the colors pop. I was happy with the result but think I could have done a slightly better job editing, potentially creating a sharper image.

Works Cited

1. “A Scientific Soap Opera, Starring the Marangoni Effect.” *UCSB College of Engineering*, 24 Jan. 2018, https://engineering.ucsb.edu/news/scientific-soap-opera-starring-marangoni-effect.
2. “Multiphysics Cyclopedia.” *COMSOL*, https://www.comsol.com/multiphysics/marangoni-effect.
3. “How Does Soap Work?” *ChagrinValleySoapAndSalve.com*, Chagrin Valley Soap And Salve Company, https://www.chagrinvalleysoapandsalve.com/blog/posts/how-does-soap-work/.
4. “Physical Properties of Milk.” *Physical Properties of Milk | Food Science*, https://www.uoguelph.ca/foodscience/book-page/physical-properties-milk.