

UNIVERSITY OF COLORADO - BOULDER

MCEN 5151 - FLOW VISUALIZATION

IMAGE 2 REPORT

Marangoni Effect Patterns

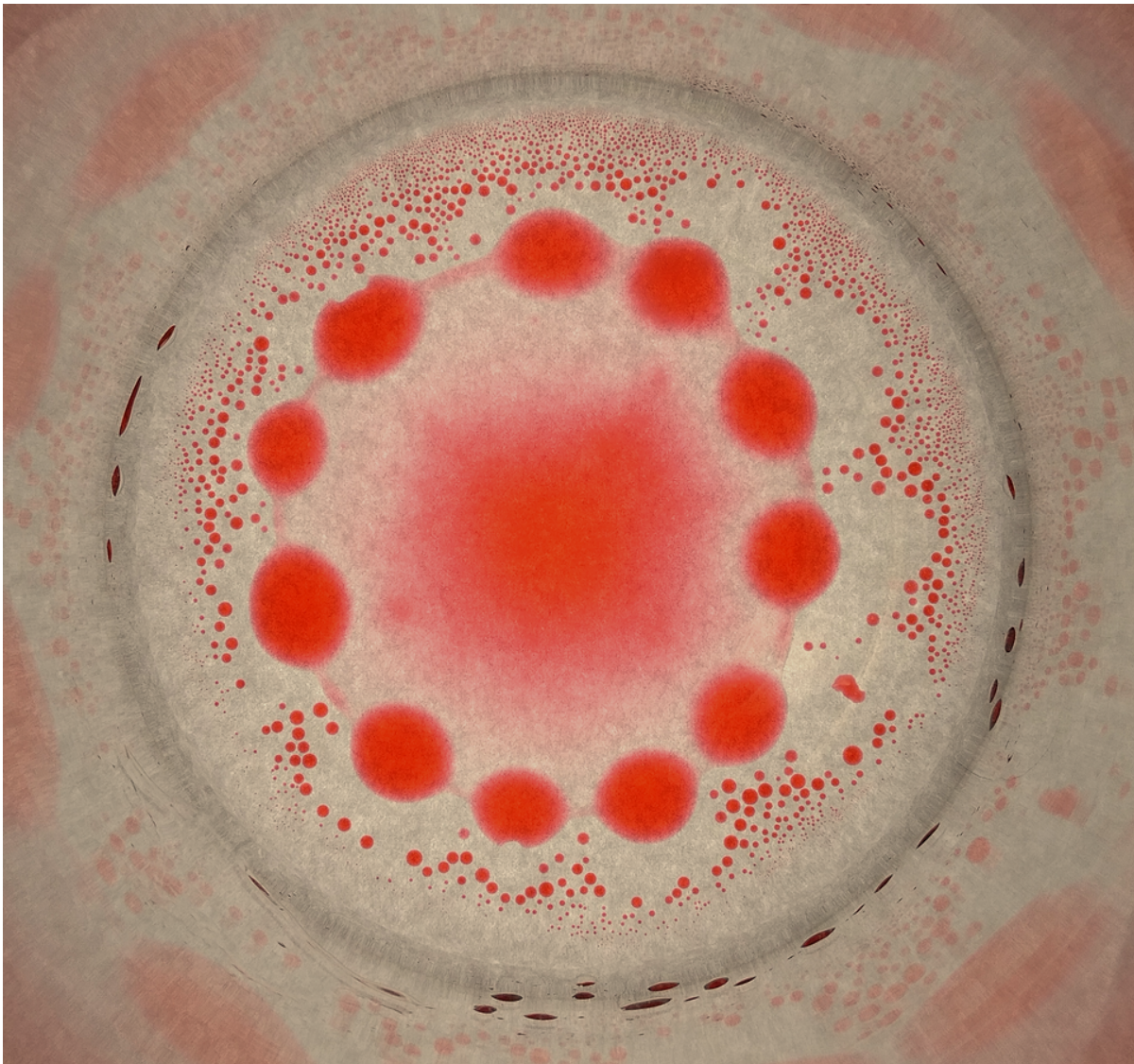
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I. Introduction

The purpose of this picture is to explore photography as a means of capturing interesting fluid phenomena. In this case, the fluid phenomena is known as the Marangoni Effect. In contrast to my previous image (surface tension on a leaf), this one took significantly more setup and experimentation in order to capture. The following report showcases the experimental setup and procedure, discusses the flow phenomena, and outlines the photographic techniques (including post-processing) used to obtain the final image.

II. Experimental Setup and Procedure

Fig. 1, shown below, is a visual representation of the setup for how this image was captured. To start, sunflower oil was poured into the bottom of a beaker. Neither of these choices, sunflower oil and a beaker, are explicitly required, but sunflower oil is exceptionally clear (unlike other oils) and most beakers do not have any labelling, indentations, or markings on their bases (unlike most household glasses). A piece of paper was placed below the beaker, resting on a 1/2in piece of clear acrylic in order to better diffuse the light placed below. Afterwards, 99% isopropyl alcohol was mixed with regular tap water in a separate glass, with a roughly one to one ratio, and a significant amount of red food dye (enough to make it blood-red) was added. It should be noted that some food dyes do not dissolve very easily in the water/alcohol mixture, a gel based food dye was used and it required significant mixing in order to get clumps to diffuse properly. Lastly, not pictured in the diagram, is the eye dropper that was used to gently place the mixture on top of the oil layer to create the reaction.

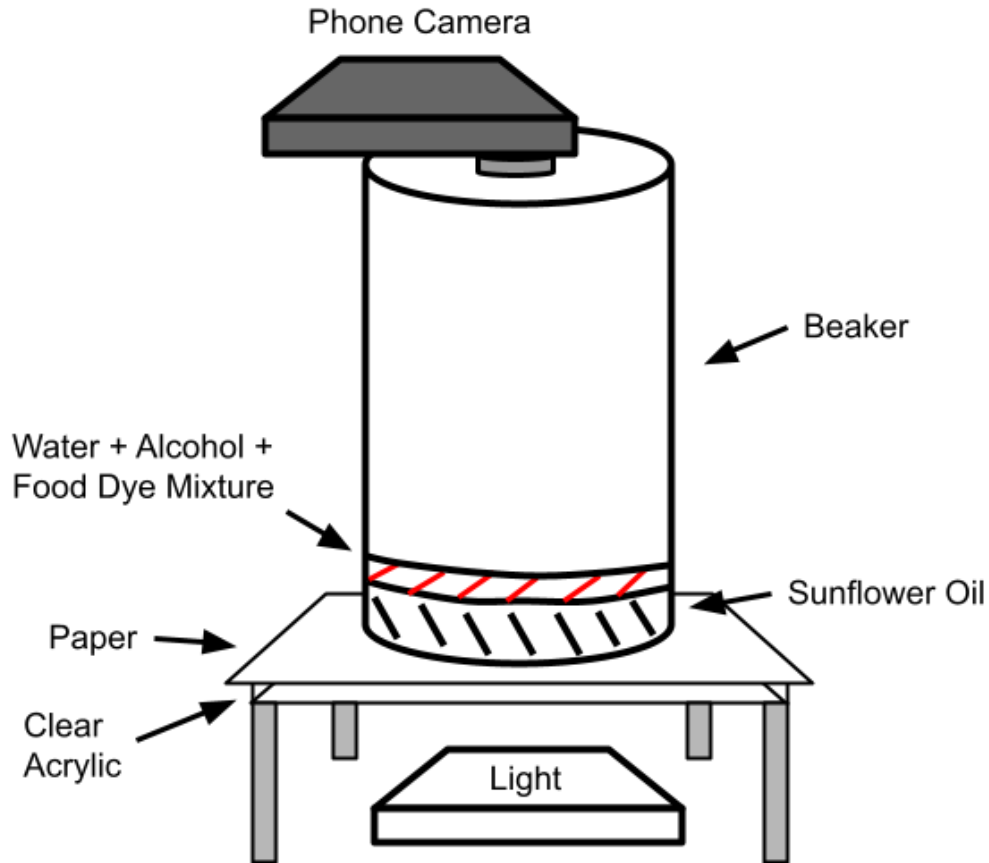


Fig. 1 Diagram of Setup

Several experiments, changing the ratio between the water and alcohol, were needed before getting the exact effect seen in the final image. Also, it is recommended that the water-alcohol mixture is made last in the procedure in order for the alcohol to not evaporate before performing the experiment.

III. Flow Discussion

As mentioned earlier, the effect seen in the image is called the Marangoni Effect, named after an Italian physicist from the 19th century [1]. In simplest terms, the Marangoni effect is created when a surface tension gradient exists across the surface of a liquid. This is seen in a variety of ways, as noted by Colin D. Bain in an article from *Advances in Colloid and Interface Science*, "Examples include the draining and coalescence of foams, collisions of emulsion droplets, break-up of jets, spreading of drops on surfaces and mixing of fluids" [2]. In the case of this experiment, the effect

is created between the low surface tension of isopropyl alcohol and the high surface tension of water, 20.93 dyne/cm and 71.97 dyne/cm at 25 °C, respectively [3, 4]. The gradient caused from the evaporation of the alcohol in the mixture causes the mixture to get "pulled" towards the rim of the beaker, as fluid flows from low surface tension to high surface tension (alcohol to water). The oil does not factor into this effect, it simply serves as a medium for the mixture to rest on and flow with little friction.

IV. Photography Technique

This image was taken with a simple smartphone camera, although manual adjustments were taken within the "pro mode" in order to change ISO, aperture, and get a sharper focus. Similar to how I took my previous image [5], the ISO was lowered in order to reduce as much noise as possible, and shutter speed was adjusted as necessary in order to accommodate for the darkness of the image. This resulted in the sharpest image possible considering the sensor that was used. The specific camera settings are listed below:

- Camera: 16 MP Sony IMX 298 sensor (in a OnePlus 3 smartphone)
- Aperture: f/2
- Focal Length: 4.26mm
- ISO: 100
- Shutter Speed: 1/125s
- Original Size: 2610 x 4640p

Darktable was the program used for post-processing of the image (the appendix includes the original image for reference). To start, some cropping was done in order to center the bottom of the beaker in the frame. I purposefully chose to leave some of the surroundings (namely, the walls of the beaker) in order to add some context for the viewer (the reflections are also somewhat visually interesting as well). Secondly, the image was made slightly warmer (white balance adjustment) in order to eliminate the harsh blueish background created by the LED back-lighting and in order to emphasize the red food dye in the mixture. Lastly, the sharpness was increased slightly in order to make the smaller beads, found along the rim, easier to see.

V. Conclusion

A few key critiques were given regarding the photo in class. Firstly, rather than changing the white balance of the photo in order to brighten the red and eliminate the blueish background, using the "color zones" in Dartable to make adjustments to specific colors which would definitely be an improvement. Also, it might have been preferable to eliminate the surrounding image outside of the subject (base of the beaker), despite the context that it brings. While the final photo is not perfect, it definitely exceeded by expectations. The experiment was very enjoyable to perform, and the effects seen real time were a sight to behold.

References

- [1] Meggs, L., "The Marangoni Effect: A Fluid Phenom," *International Space Station Program Science Office*, 2011. URL https://www.nasa.gov/mission_pages/station/research/news/marangoni.html.
- [2] Bain, C. D., "The overflowing cylinder sixty years on," *Advances in Colloid and Interface Science*, Vol. 144, No. 1, 2008, pp. 4–12. <https://doi.org/https://doi.org/10.1016/j.cis.2008.08.006>, URL <https://www.sciencedirect.com/science/article/pii/S000186860800122X>, designer Molecules for Interfacial Activity, in honour of Alan R. Pitt.
- [3] "PubChem Compound Summary for CID 3776, Isopropyl alcohol," *National Center for Biotechnology Information*, 2021. URL <https://pubchem.ncbi.nlm.nih.gov/compound/Isopropyl-alcohol>.
- [4] "PubChem Compound Summary for CID 962, Water," *National Center for Biotechnology Information*, 2021. URL <https://pubchem.ncbi.nlm.nih.gov/compound/Water>.
- [5] Stone, S., "Leaf Droplet Surface Tension," *University of Colorado Boulder*, 2021. URL <https://www.flowvis.org/wp-content/uploads/2021/09/ShawnStoneImage1Report.pdf>.

VI. Appendix

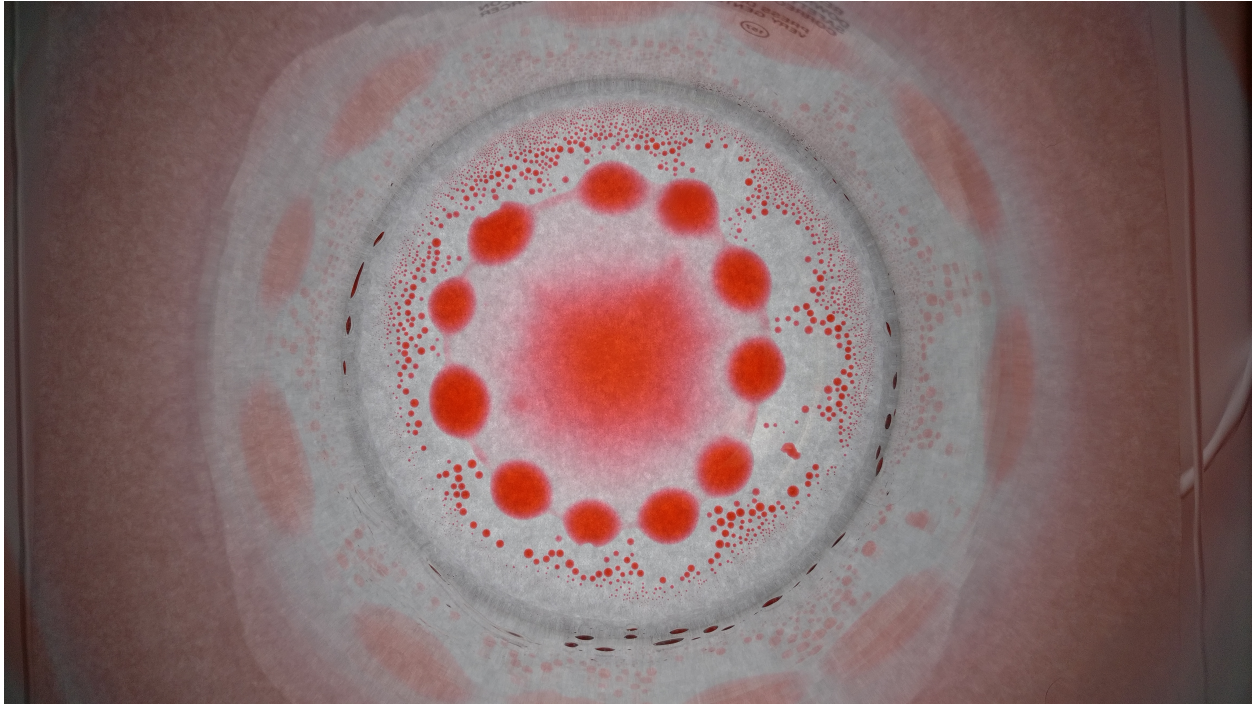


Fig. 2 Original Unedited Image