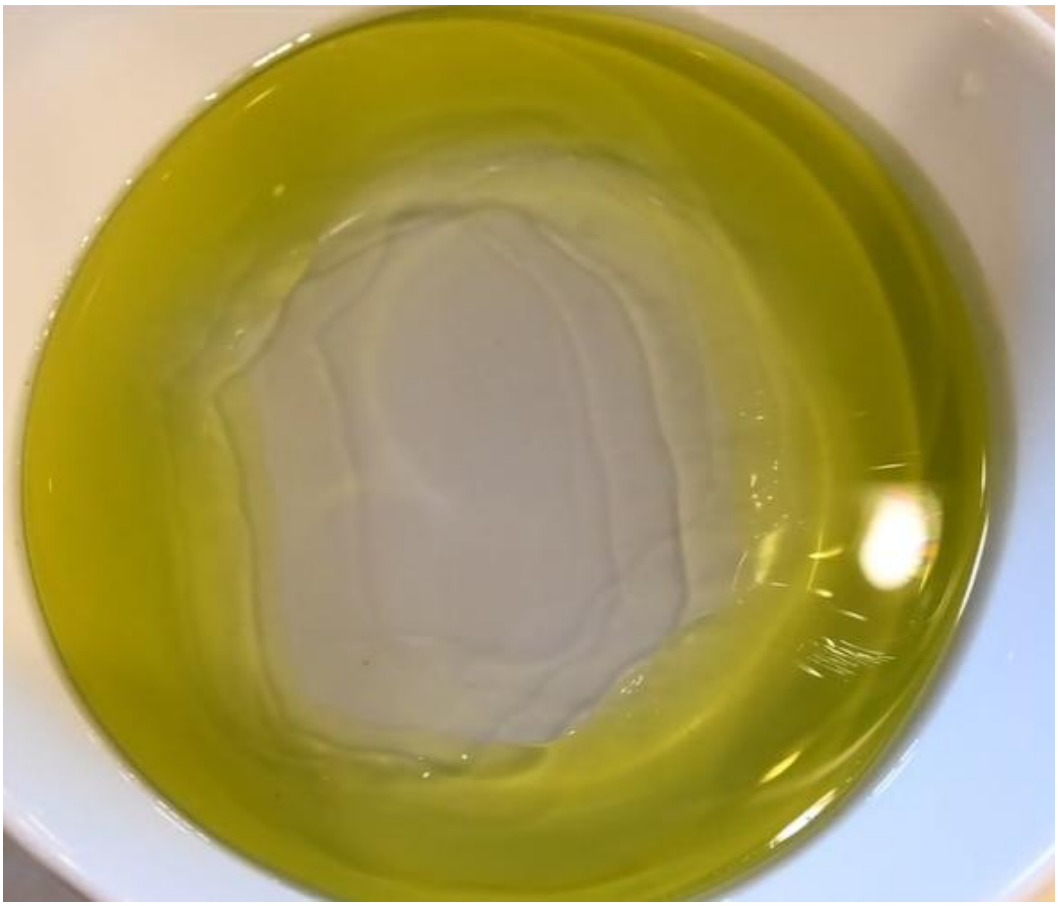
Oil and Soap



Tegan Chanders
Get Wet Report
MCEN 5151: Flow Visualization
Dr. Sunberg
9/18/2026

Introduction

This video was created for the Flow Visualization class at CU Boulder. The class is where art meets science and focuses on explaining the physics behind flow phenomena. The goal of this experiment was to create a visually appealing image from the interaction between water surface tension and soap. Initial experiments included sprinkling pepper on water and then sticking a toothpick with soap on it into the middle of the pepper. A number of different combinations of materials were tested, but ultimately the best result came from a single floating disk of olive oil on top of water in a bowl. A toothpick with soap was then inserted into the middle of the disk, and the resulting reaction was filmed. A DSLR was used to take the final video. Help with the set up was received from a classmate, Gavin Lopez.

Experiment Setup

The experiment was set up on a counter in a kitchen. A white bowl was placed on the counter and filled with 2 inches of sink water. Around a 1/4 cup of extra virgin olive oil was gently spooned on top of the water. This was done gently so the oil did not mix with the water. The oil formed a disk in the center of the bowl. Enough oil was added so that the disk almost covered the entire surface of the water in the bowl, which had a diameter of about 6 inches. The bowl was lit with a 10 W LED light positions 3 feet above the bowl. A camera was mounted on a tripod above the top of the bowl and angled down to look into the bowl. The tip of a toothpick with a diameter of 0.08 inches was covered in dish soap. This toothpick was then inserted through the middle of the oil disk and into the water, and a video of the reaction was recorded. Once the oil had fully expanded, the toothpick was taken out of the liquid and the video continued until the movement of the oil had slowed. The experiment setup is shown below in Figure 1. Images of the setup are shown below in Figure 2.

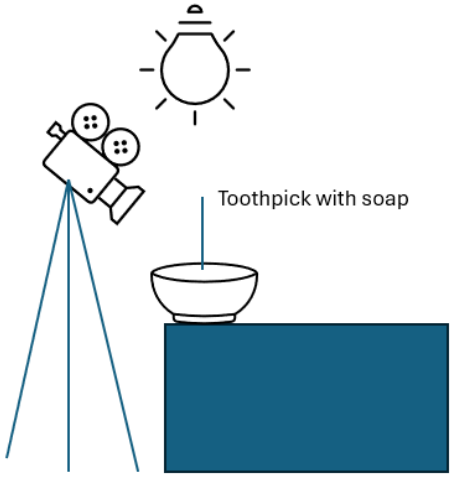


Figure 1. Experiment setup diagram



Figure 2. Experiment setup images

Flow Physics

The first phenomenon shown in this experiment is the difference in densities of two fluids. At room temperature (70ºF), water has a density of 0.99802 $\frac{g}{cm^3}$ [1] and extra virgin olive oil has a density of 0.9130 $\frac{g}{cm^3}$ [2]. Because oil is less dense, the water pushed up on the oil with more force than gravity pulls down on the oil, so it floats on top of the water. The density of olive oil can actually be used to determine the grade of the oil which is super interesting.

The second phenomenon is surface tension, and it is the key to this entire mysterious movement. Surface tension is caused by the bonds between molecules. The molecules on the surface of the liquid are attracted to the molecules in the bulk but are unable to interact with the molecules of the adjacent gas. This causes the molecules on the surface to be pulled towards the bulk since the net force on the molecules points towards the bulk. This is what causes water drops to be spherical. Another way to think about it is that the fluid tries to minimize its surface area. Surface tension is also what holds the oil molecules together in a disk on top of the water. [3]. Water has a relatively strong surface tension because it has hydrogen bonding between its molecules [4]. Hydrogen bonds on strong and therefore the water molecules are attracted to each other more and are pulled towards the bulk with more force. Water's surface tension at 70ºF is 64.4 $\frac{mN}{m}$ [5] compared to olive oil which has a surface tension of 31.9 $\frac{mN}{m}$ [6] at 70ºF.

Soap is an alkaline salt and is designed to remove dirt and grease from objects. Soap acts as a surfactant which means it gathers at water surfaces and changes the properties of the water surface [7]. Surfactants do this because they have a polar end and an apolar end. The water molecules are attracted to the polar side of the soap, and the apolar side of the soap is repelled by the water. This causes the water molecules to not be attracted to each other as strongly and thus lowers the surface tension to about 25 $\frac{mN}{m}$ which is half of what it was originally [8].

Once the soap on the end of the toothpick has been inserted into the water in the middle of the bowl, the water surface tension in the center breaks. The causes an imbalance in force because the surface tension in the center of the bowl is now pulling less strongly. This force pulls the water to the edges of the bowl in a ring starting from where the soap was inserted. This resulting movement driven by a difference in surface tension is called the Marangoni effect [9]. The water moving towards the edge of the bowl causes the oil to move with it, which creates the visual in the video. The soap does not significantly alter the surface tension of the oil, which can be seen in the video because the ring only propagates out once the soap passes through the oil and reaches the water.

The Weber number is a dimensionless number that relates inertial forces to surface tension forces in a fluid. It is defined by the Equation 1 and Table 1 below [10].

$$We = \frac{\rho v^2 L}{\sigma} \quad \text{(Equation 1)}$$

Table 1. Weber equation variables

Water Variables	Values
Density: ρ	$0.99802 \frac{\text{g}}{\text{cm}^3}$
Velocity: v	$0.025 \frac{m}{s}$
Characteristic length: L	0.075 m
Surface tension: σ	$64.4 \frac{mN}{m}$

The density and surface tension of water at 70ºF were used for the Weber equation. The velocity of the water moving was estimated from the time it took the water to move from the center of the bowl to when it stopped moving outwards. This was approximately 2 seconds, and it approximately moved over 2 inches in that time. Using these numbers, a velocity of $0.025 \frac{m}{s}$ was estimated. The characteristic length of the bowl radius was chosen as it is the distance over which the surface tension acts. Plugging these numbers into Equation 1 yields the following results.

$$We = \frac{\left(998.02 \frac{kg}{m^3}\right)\left(0.025 \frac{m}{s}\right)^2 (0.075\, m)}{\left(0.0644 \frac{N}{m}\right)} = 0.73$$

The Weber number before the soap is inserted is 0 because the fluid is stationary. The Weber number after the surface tension breaks is 0.73. A Weber number around 1 generally describes a transitional flow where surface tension and inertial effects are both important [11]. This makes sense because the surface tension is half of what it was initially but is still a significant force.

Visualization Technique

The visualization technique of marked boundary was used in this experiment. Marked boundary is when there are two visually distinct fluids and the boundary between them shows the flow of the fluids. In this case, the boundary between the water and the oil shows the movement of the water and oil caused by the reduction of the water surface tension. This boundary can be easily seen because the water is translucent with a white background and the oil reflects yellow light which differentiates it from the water and bowl.

Photography and Post Processing

The video was shot using a DSLR camera with the specifications shown in Table 2.

Table 2. Camera specifications

Camera Model	Nikon D7500
Lens	AF-S NIKKOR 24-70mm 1:2.8G ED
Focal Lenth	24 mm
ISO	3200
Shutter Speed	1/100
Aperture	f5
Video Resolution as Shot	1920x1080 pixels
Video Frame Rate	60 frames/second
Field of View	52.5º horizontal, 36.0º vertical

The video was taken approximately 8 inches away from the bowl. The camera was mounted on a tripod to keep the video still. The bowl was lit from above with a 10W LED light bulb. The settings were used to balance the exposure and provide good visual quality. The video was edited in Filmora and was cut to be 17 seconds long which includes the insertion of the toothpick until the movement of the oil slows. The audio was removed as it did not contribute to the experiment. The video was cropped to focus on just the bowl but was curiously still 1920x1080 pixels, possibly caused by a setting in the video editor's exporting process. The video's speed was not adjusted, and it plays at real time.

Conclusion

The video reveals the interaction between water surface tension and soap. The oil shows the movement of the water as the surface tension breaks and pulls the oil towards the sides of the bowl. The intent of the experiment was to show this interaction and explain the physics behind the almost magical movement. The author likes the interesting movement but dislikes the reflections of the overhead lights. The video could be improved by having a straight overhead view of the bowl and diffusing the lighting more so there aren't any bright spots. Future work could include timing the movement of the oil and also looking deeper into why the oil returns in the pattern it does.

References

[1] Water Science School, “Water Density,” USGS, Oct. 22, 2019. https://www.usgs.gov/water-science-school/science/water-density (accessed Sept. 17, 2026).

[2] Mi Olivia Gourmet, “Density of Extra Virgin Olive Oil,” *Mi Oliva Gourmet*, Jan. 05, 2022. https://en.miolivagourmet.com/blogs/mi-oliva-gourmet-blog/olive-oil-density (accessed Sept. 17, 2026).

[3] “Tension Surface - an overview | ScienceDirect Topics,” www.sciencedirect.com. https://www.sciencedirect.com/topics/engineering/tension-surface (accessed Sept. 17, 2026).

[4] S. Lower, “7.3: Hydrogen-Bonding and Water,” *Chemistry LibreTexts*, Oct. 03, 2013. https://chem.libretexts.org/Bookshelves/General_Chemistry/Chem1_(Lower)/07%3A_Solids_and_Liquids/7.03%3A_Hydrogen-Bonding_and_Water (accessed Sept. 17, 2026).

[5] Editor Engineeringtoolbox, “Surface Tension - Water in contact with Air,” *Engineeringtoolbox.com*, Jan. 25, 2004. https://www.engineeringtoolbox.com/water-surface-tension-d_597.html (accessed Sept. 17, 2026).

[6] S. N. Sahasrabudhe, V. Rodriguez-Martinez, Meghan. O’Meara, and B. E. Farkas, “Density, viscosity, and Surface Tension of Five Vegetable Oils at Elevated temperatures: Measurement and Modeling,” *International Journal of Food Properties*, vol. 20, no. Sup2, pp. 1–17, Dec. 2017, doi: 10.1080/10942912.2017.1360905.

[7] LibreTexts, “8.3: Soap,” *Chemistry LibreTexts*, July 25, 2022. https://chem.libretexts.org/Courses/Williams_School/Chemistry_II/08%3A_Biomolecules_-_Lipids/8.03%3A_Soap (accessed Sept. 17, 2026).

[8] “Surface tension,” *labs.phys.utk.edu*. https://labs.phys.utk.edu/mbreinig/phys221core/modules/m7/surface_tension.html (accessed Sept. 17, 2026).

[9] “What Is the Marangoni Effect?,” www.comsol.com. https://www.comsol.com/multiphysics/marangoni-effect (accessed Sept. 17, 2026).

[10] “Weber Number,” www.engineeringtoolbox.com. https://www.engineeringtoolbox.com/weber-number-d_583.html (accessed Sept. 17, 2026).

[11] M. Milbury and J. Ratzlaff, “Weber Number,” *Piping Designer*. https://piping-designer.com/properties/fluid-mechanics/960-fluid-dynamics/180-weber-number# (accessed Sept. 17, 2026).