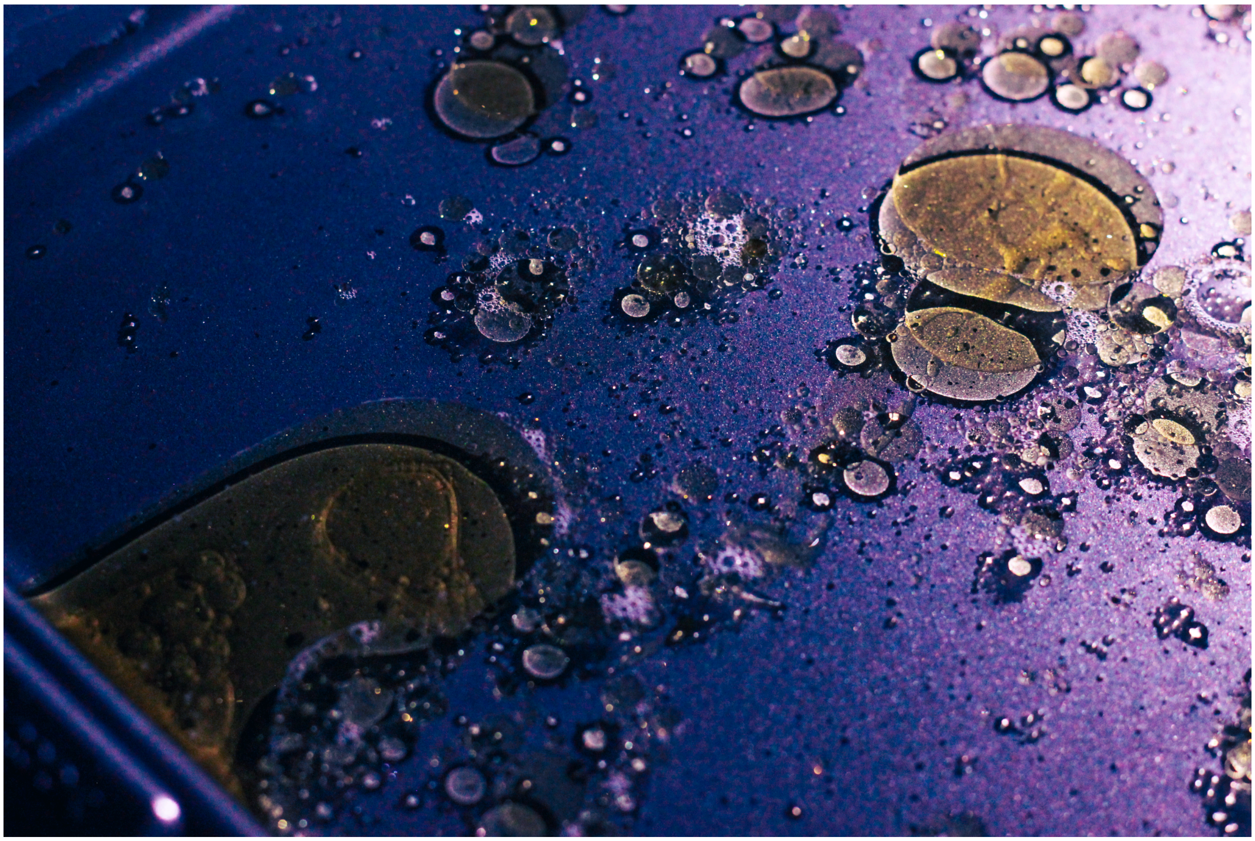
TEAM SECOND REPORT



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Team Second
ATLS 4151 – Flow Visualization

Oil-on-Water Instabilities Driven by a Soap-Induced Marangoni Effect

This image was created for the Team Second assignment in ATLS 4151: Flow Visualization. Our goal was to capture the behavior of immiscible fluids, cooking oil and water, when subjected to a deliberate surface-tension disturbance. To activate the flow, we used a soap trigger, applying a microscopic amount of dish soap to the water surface to create a strong local decrease in surface tension. This generated Marangoni stresses that caused the oil to retreat, fragment, and form the bubble-like clusters visible in the final image. Although the water was clear during the experiment, the image was later color-graded to enhance contrast between the oil droplets and the water surface.

The apparatus consisted of a shallow cooking tray approximately 30 × 20 cm filled with 1–2 cm of tap water. Drops of cooking oil were added using a pipette to allow control over droplet size and spacing. Once the oil dispersed across the surface, we initiated flow by lightly touching the water with a toothpick dipped in a tiny amount of dish soap. Because soap sharply lowers surface tension, this produced a rapid redistribution of forces along the interface, and the oil retreated from the soap point. Larger films shattered into smaller droplets, while pre-existing droplets migrated, coalesced, or broke apart depending on the stress distribution. The bubbly microstructures in the image originated in regions where the soap-induced retraction pulled thin films into unstable shapes that collapsed into clusters of small droplets.

The flow behavior is governed primarily by viscous and interfacial forces rather than inertia. To estimate the flow regime quantitatively, a characteristic spreading velocity of approximately $U = 0.01\ \mathrm{m/s}$ was observed. A representative oil droplet diameter scale is $D = 0.002\ \mathrm{m}$, and the kinematic viscosity of water is $\nu = 1 \times 10^{-6}\ \mathrm{m^2/s}$. The Reynolds number is therefore:

$$Re = \frac{UD}{\nu} = \frac{(0.01)(0.002)}{1 \times 10^{-6}} = 20.$$

A Reynolds number on the order of 20 indicates that the flow is dominated by viscous damping. This low-Re regime explains the smoothness of the flow boundaries and confirms that the fragmentation of the oil is caused not by turbulent breakup but by surface-tension gradients, the hallmark of Marangoni-driven motion. When soap reduces surface tension in one region, fluid is pulled away from that location toward regions of higher surface tension, generating spreading fronts, ruptures, and the textured droplet fields evident in the final image.

To visualize the flow, we relied on natural differences in refractive index between oil and water, along with deliberate lighting and post-processing to increase contrast. The water was not dyed; instead, we created the purple-blue appearance through color grading after capture. The soap trigger was the key visualization tool, as the Marangoni effect introduced dynamic, easily observable patterns that reveal how sensitive immiscible interfaces are to surface-tension gradients. Illumination was provided by a phone flashlight placed at a shallow grazing angle, producing specular highlights on the oil droplets and emphasizing subtle surface textures. The surrounding room was dark to ensure the side-lighting controlled all highlights and shadows.

The photographic setup consisted of a Canon EOS Rebel T3i with a Canon EF 50mm f/1.8 II lens positioned approximately 15–20 cm above the water surface. This focal length provided both crisp detail and a shallow depth of field, allowing the droplet clusters to stand out against the background. The original image resolution was 5184 × 3456 pixels in sRGB color space. Exposure settings were ISO 3200, shutter speed 1/80 s, and aperture f/4, all shot in full manual mode. These settings were chosen to balance the low-light environment with the need for sufficient depth of field and minimal motion blur. In post-processing, the raw file was color-graded to shift neutral tones into a cooler palette, and adjustments were made to contrast, clarity, and noise reduction. No structural alterations were performed; the fluid patterns remain exactly as captured.

The final image reveals the complex interplay between immiscible fluids, surface-tension gradients, and soap-induced Marangoni flow. The fragmented oil patches and clusters of microbubbles demonstrate the sensitivity of thin films to even small perturbations. I particularly appreciate how the color grading transforms the physical scene into something resembling a cosmic or microscopic landscape, without compromising the accuracy of the physical phenomena displayed. If I were to continue developing this project, I would explore capturing the transient motion with high-speed video or experiment with varying soap concentrations to control the strength and geometry of the Marangoni fronts. Overall, the image successfully fulfills the intent of illustrating a surface-tension-driven flow in an aesthetically compelling way.

References

"Marangoni Effect Explained." *Physics World*, 2022.

"Surface Tension Gradients and Soap Film Dynamics." University of Cambridge Fluids Group.

"Why Oil and Water Don't Mix." *Scientific American*, 2019.