Diffusion of Colored Corn Syrup

9/30/2025 - Team First

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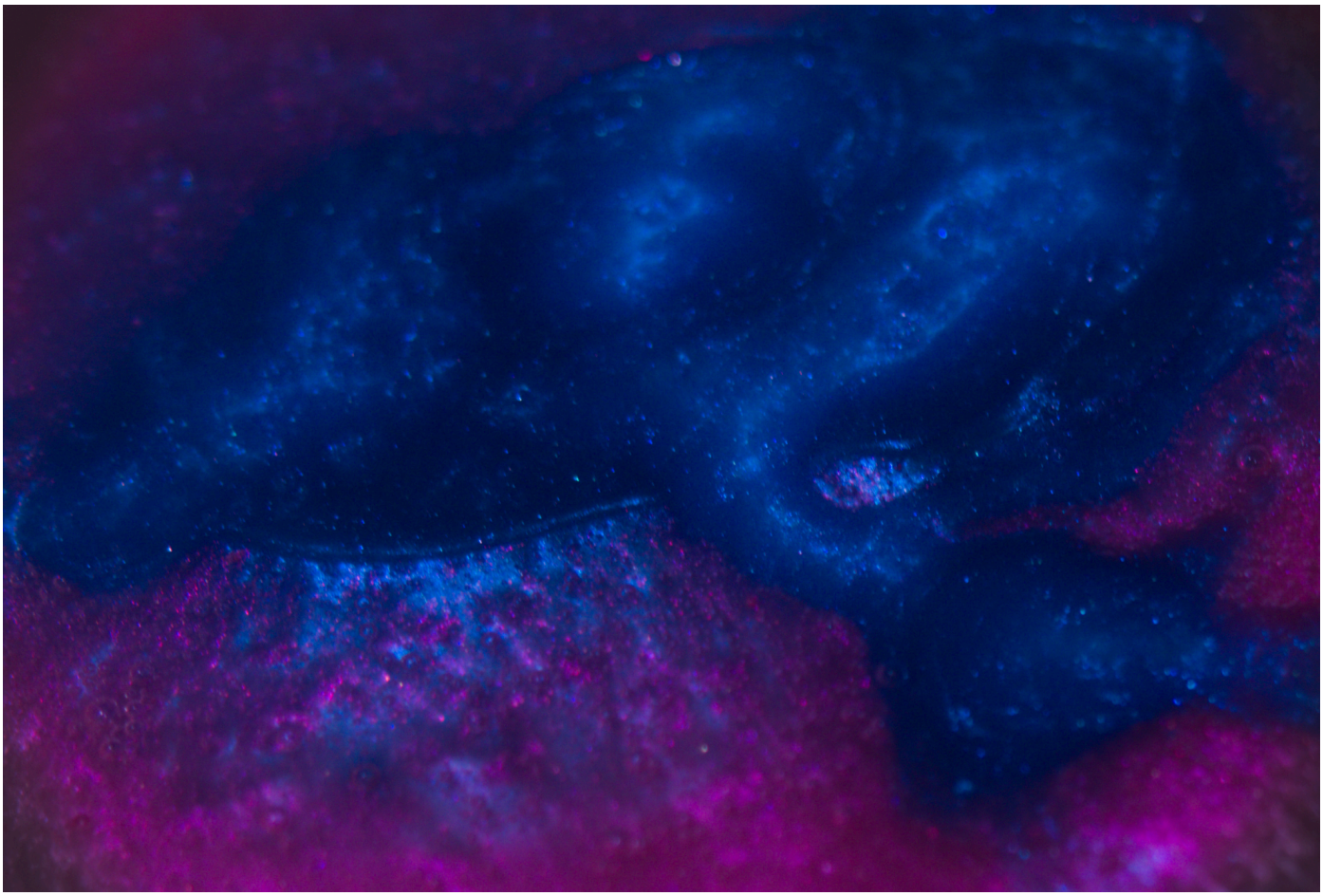
Flow Visualization - 002



Introduction

The primary purpose of the image I created is to visualize the viscous fluid physics of a fluid that is much denser than many others. Originally I wanted to capture the viscous coiling that occurred when the stream impacted the plate, but in doing that I found that the patterns created by the spreading fluid were beautiful. We used an edible Luster Dust, which acts like mica powder but is much more environmentally friendly, to create a rheoscopic effect in the corn syrup which would allow us to visualize the interactions much easier.

Flow Apparatus

The setup for this flow visualization was decently simple. We used a photo backdrop that was checked out of the Design Center in the ITLL to ensure a clean background for the image, a 15W LED to illuminate the flow in different colors, and a glass dish to ensure a flat surface for the liquid to flow onto. While I was taking my photos and holding the light Cody poured the corn syrup from two cups about a foot and a half from the glass plate.

Flow Physics

This experiment involved many flow phenomena even though some can't be seen in the final image. As the syrup is poured, gravity accelerates the stream, which causes it to become very narrow. This is a phenomenon called vena contracta. Once the stream impacts the glass plate it forms a spiral coil, similar to a rope falling on a floor. The spreading of the two colors seen on the left side of the image is caused by advection, where the bulk motion of the fluid folds the interface between the two colored layers under itself. As the fluids flowed outward, the interface between them was stretched and sheared. The appearance of "diffusion" is actually extremely thin layers of one color being drawn into the other and not actual molecular diffusion.

$$Re = \frac{\rho v L}{\mu}$$

- Characteristic length (L): 0.25 cm = 0.0025 m
- Characteristic velocity (v): ~15cm/s = 0.15 m/s
- Dynamic viscosity of corn syrup (μ): 52.5 Pa (Average of the range at room temperature)
- Density of corn syrup (ρ): 1.4 g/cc

Using the numbers listed above I calculated the Reynolds number for the corn syrup as 0.00001. This number is incredibly small, which means that the corn syrup behaves as a laminar flow. This is consistent with the even diffusion that can be seen and the lack of eddies.

$$Pe = \frac{vL}{D}$$

- Mass Diffusion Coefficient (D): 10^{-10} m^2/s

Using some of the same numbers from Re as well as the diffusion coefficient, I calculated the Peclet number for the corn syrup as 3,750,000. This number is extremely high, which shows that advection entirely dominates diffusion in this process. The advection in the bottom left of the image is the flow stretching and thinning the interface between the two colors into microscopic layers, which is called kinematic mixing or shearing.

- Time resolution = 1/100 second
- Spatial resolution = (0.15 m/s) / (1/100 s) = 0.0015m

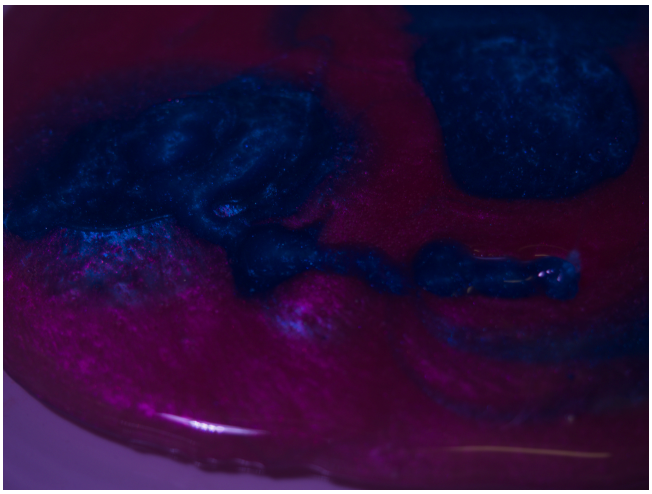
Visualization Technique

The visualization technique used in this project is dye visualization, with edible Luster Dust serving as the dye. The experiment was conducted indoors under climate-controlled conditions with minimal airflow in the vicinity. The surface the dish was on was level and once the experiment was set up the plate and background weren't touched again. There were no dilutions of the corn syrup. For lighting we used a 15W RGB-LED held about a foot from the fluid. The LED constantly cycled through the color spectrum so we used burst shooting to get images of the fluid under every color.

Photographic Technique

To take this photo the Olympus OMD E-M5 MKii was used, along with the M.Zuiko 14-42mm f/3.5-22 lens from Olympus. The below settings were chosen because the flow was incredibly slow and viscous and the lighting was very bright.

- ~8 inches from surface of corn syrup
- Digital Mirrorless, 4639 x 3471 px, 2453 x 1656 px
- f/4.7, 1/100 s, ISO 250, ~40° FOV
- Crop, Vignette, Exposure (increasing on bright parts, decreasing darker parts, and brightening the whole image), Tone Equalizer, Retouch (to remove a few bubbles near the main flow)



Analysis and Possible Improvements

I'm very proud of this image overall. I believe that the Luster Dust really shows the flow that I wanted to highlight, that being the advection between the two colors. I think that the choice to use a colored LED really helped the overall look by increasing the saturation and contrast between the two colors of corn syrup, and my editing adds a lot without detracting from the physics. If I were to redo this visualization I would have used a smaller aperture to make sure that the entire image is in focus, and would have gotten a bit closer to the fluid surface with my camera. I would love to try this experiment again with even more colors, maybe trying to see the advection between 3 or even 4 different colors.

References

1. Van Dyke, M. (1982). *An Album of Fluid Motion.* Parabolic Press.
2. Smits, A. J. (2012). *Flow visualization: techniques and examples*. World Scientific.
3. Karch, G.K., Sadlo, F., Weiskopf, D., Munz, C.-D. and Ertl, T. (2012), Visualization of Advection-Diffusion in Unsteady Fluid Flow. Computer Graphics Forum, 31: 1105-1114. https://doi.org/10.1111/j.1467-8659.2012.03103.x