# Team Third - Fall 2025

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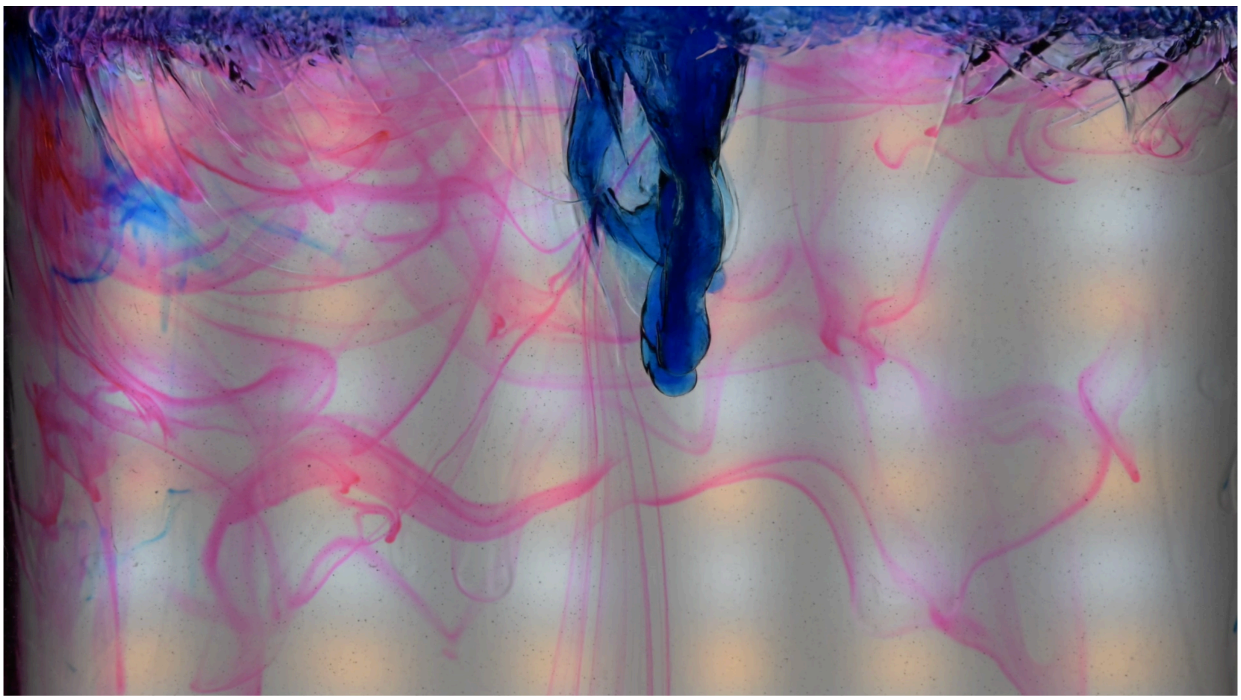
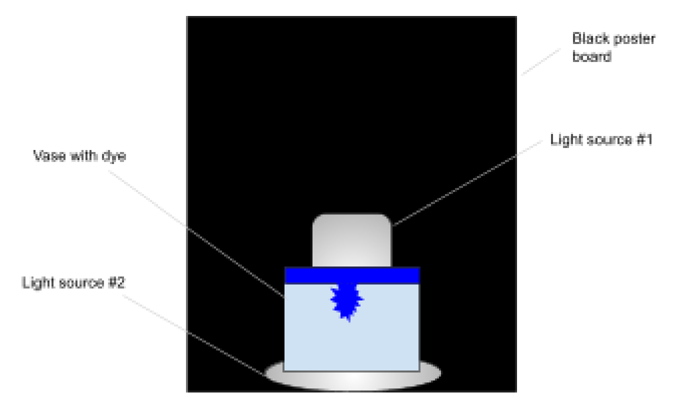


## Purpose and Context

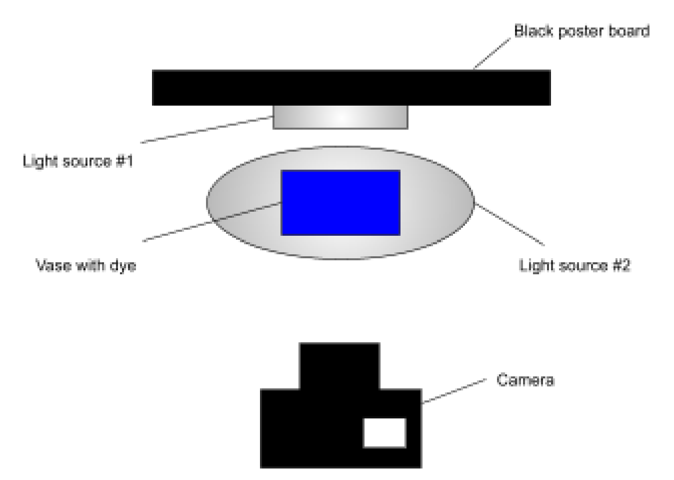
This image was created with the intention of dropping a 3D-printed “teardrop” shape through a glycerin-water solution, observing the effects of different densities and viscosity between mixtures. However, since the aforementioned experiment did not turn out as planned, this videoed phenomenon instead reveals the reaction when a 3-part glycerin, 1-part water solution is met with a water-diluted food dye injection. This interesting fluid flow is a result of differences in density and varying viscosities amongst the two mixtures. I would like to thank both Luke Freyhof and Xeen Meighan for their assistance in capturing this image!

# Materials and Methods

The initial setup for this experiment consisted of a tripod for the camera, a glass vase, two different light sources, a black poster board, and two solutions (one consisting of the 3-1 water-glycerin and one as the diluted food dye mixture. Provided below is a sketch of the apparatus that was used to capture this flow phenomena, from both the camera's perspective and the perspective of a viewer looking down on the setup.




Camera POV




Top-down POV

**Figure 1:** Experiment setup

Once the camera was secured to the tripod, it was moved to about 22 inches away from the center of the vase. There was one 1800-lumen, USB-powered led panel lighting the setup from behind the vase and one led/blacklight panel lighting the surface from underneath. To aid in this process, the team decided to place a black canvas behind the tank to allow for the contrast to be seen more clearly. This was a lesson that we took from the Team First and Team Second experiments, and decided that it provided very clear images that were needed in post-processing. These two light sources provided enough back and under lighting to accurately portray the effect of different density fluids interacting as well as the viscous driving factors that caused the observed fluid phenomenon.

# Fluid Dynamics

The fluid phenomenon observed throughout this experiment occurs as a result of two key factors: differences in density between the two fluid combinations and the viscosity influence that leads these two fluids to interact in the manner that they do. When the diluted food dye first enters the thick, denser glycerin-water mixture, it breaks through the thick layer at the top of the glass vase. This results in finger-like clouds of dye which stream through the glycerin and water, forming some cloud formations. These actually form as a result of some Rayleigh-Taylor instabilities that are present in this system, as referenced by Sharp in this snippet of text describing this type of flow: “The Rayleigh-Taylor instability is a fingering instability of an interface between two fluids of different densities, which occurs when the light fluid is pushing the heavy fluid” [1]. When these two fluids first interact, the diluted water-dye solution acts as a “more dense” fluid as there is a greater force pushing the fluid down into the glass vase. However, once friction takes over and slows the fluid down, it begins to rise toward the top of the tank. This is thanks to the difference in density between the two fluids, characterized by the Reynolds Number in the following equation:

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

where ρ is the fluid density of the water-glycerin solution (~1065 $\frac{kg}{m^3}$), $v$ is the velocity of the injected food dye (0.03 $\frac{m}{s}$), L is the length of the entering stream (25.4 mm), and μ is the viscosity of the is the clear solution in the vase ($2.9 * 10^{-6}\frac{m^2}{s}$). Using these values and plugging into the Reynolds Number equation, we find the following value for this experiment:

$$Re = \frac{\rho v L}{\mu} = \frac{(1065\ \frac{kg}{m^3}) * (0.03\ \frac{m}{s}) * (25.4 * 10^{-3} m)}{2.9 * 10^{-6}\ \frac{kg}{ms}} = 27983.79$$

This high Reynolds Number shows that we are experiencing flow that is driven by turbulence, as can be supported by the finger-like tendrils that extend throughout the tank when the dye is initially injected. The viscosity causes the thinner, less dense fluid to want to spread, slip, and rise back up through the fluid. Since the clear fluid is more viscous, it causes this process to occur rather slowly, freezing a moment in time if the dye combined with enough air to grab the dye as it rises back up to the surface (seen with the pink dye in the back, the aftermath of previous failed experiments performed in the same vase and fluid mixture). It has been proven that “in turbulent flow, viscosity contributes to the dissipation of turbulent kinetic energy. Viscosity affects the resistance or drag experienced by an object moving through a fluid” [2]. In this case, since the Reynolds Number showed that we are dealing with a highly turbulent fluid interaction, viscosity is causing the dissipation of turbulent kinetic energy, shown when the fluids stop interacting with each other and the less dense solution rises to the top of the vase.

## Visualization Techniques

The final image was captured on a Nikon Z 6 III with a 33mm lens. The following table presents the exact properties of the final image.

| Camera Settings | Value of Settings |
|---|---|
| Focal length | 33 mm |
| Aperture | f/4 |
| Shutter Speed | 1/400 s |
| ISO | 400 |
| FPS | 120 fps |
| Size | 2854×1602 pixels |

**Figure 2:** Image Properties

As stated previously, the lens was about 22 inches from the location of the flow. Given that the focal length was 33 mm, the field of view for this image turned out to be 54 inches in width and 36 inches in height.

The lighting that was chosen was fairly high, so a lower value for the ISO provided the perfect setup to capture such a well lit image. This video was also recorded at 120 fps to capture the moving fluid, though the images provided in this report are taken as screenshots from the moving fluid in the final video.

The post-processing that was completed for this image, including cropping the image to a more suitable size and removing the distortion that resulted from the layers of glass present on the sides of the glass vase. The two images below show the before and after of what post-processing was done.

| **Original Images** | **Final Image** |
|---|---|

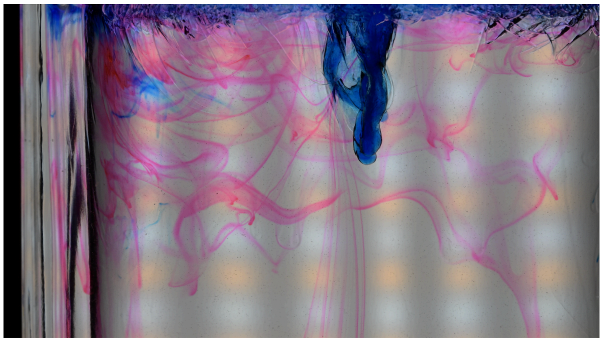
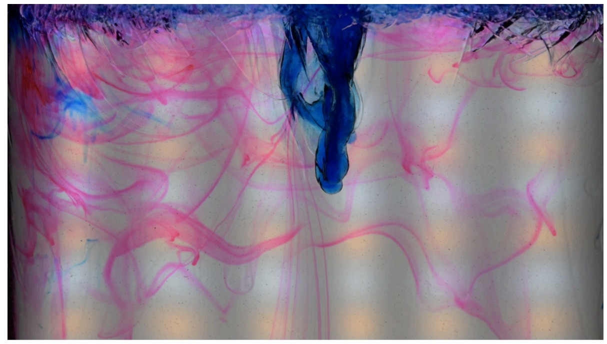
| | |
|---|---|
|  |  |
| 2866×1602 pixels | 2854×1602 pixels |

**Figure 3:** Original and Edited images

## Conclusion

The final video that we captured and processed shows the artistic beauty observed when two fluids of opposing density and viscosity meet. The fact that we were able to capture a video revealing the unexpected nature of viscosity difference highlighted by different colors is so fascinating and leads to such a unique color palette in the final production of this video representation. I think this video beautifully displays the effect that simple density differences have on ordinary flow. If I were to recreate this image, I would try to capture a video of the top-down effect of combining such liquids together. It would be interesting to see the diffusion of the two solutions together. I would also like to experiment with different camera settings to see how much of an effect the initial image settings have on the final image (after post-processing is complete). Overall, I believe this image displays the intended phenomenon from a different perspective than was initially decided upon, resulting in an interesting representation of density and viscosity driven flow.

## References

[1] *Https://Www.Sciencedirect.Com/Science/Article/Abs/Pii/S1047847720300046?Via=ihub*, www.med.upenn.edu/pmi/events/https-www-sciencedirect-com-science-article-abs-pii-s1047847720300046-via-3dihub. Accessed 22 Nov. 2025.

[2] Tanaka, Sakura. "Understanding the Role of Viscosity in Fluid Mechanics: Exploring the Effects and Applications." *Fluid Mechanics: Open Access*, Hilaris SRL, 28 Apr. 2023, www.hilarispublisher.com/open-access/understanding-the-role-of-viscosity-in-fluid-mechanics-exploring-the-effects-and-applications-98397.html.

[3] "Www.Scantips.Com." *Camera Field of View Details and Calculator (FoV)*, www.scantips.com/lights/fieldofview.html#top2. Accessed 28 Sept. 2025.

[4] *YouTube*, YouTube, www.youtube.com/watch?v=NalDxhQ6sqg&t=1s. Accessed 21 Nov. 2025.