# Flow Visualization of Rayleigh-Taylor Instability using Acrylic Paint

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Assignment: Team Second

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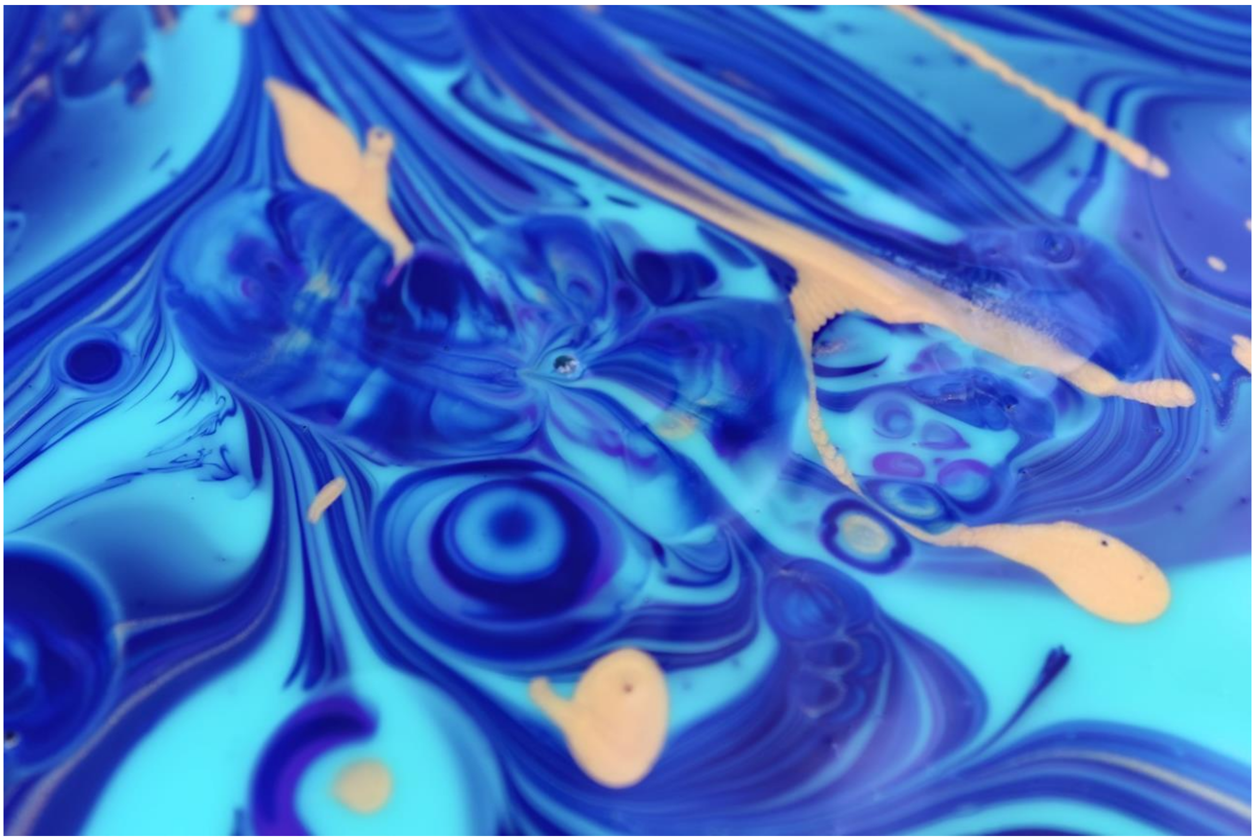

Figure 1, front view of Rayleigh-Taylor instability occurring because of acrylic paints with different densities leading to a mixture.

## Introduction

The image in figure 1 was captured for the Team Second assignment for MCEN 5151. This is a Flow Visualization course at the University of Colorado Boulder. The goal of this course is to focus on making the physics of fluid flow more visible to the human eye [1]. The intent of this image was to show the Rayleigh-Taylor instability physics phenomenon. This occurs when fluids of different densities create mixture. This image was shot with the help of Team Kohlrabi (Hannah DelGuercio, Sam Lippincott, Kenneth Olavarria). In the following report, I will discuss the phenomena and techniques used to capture this image.

## Fluid Physics

Below in figure 2 is a diagram of the flow visualization apparatus used for this photo.

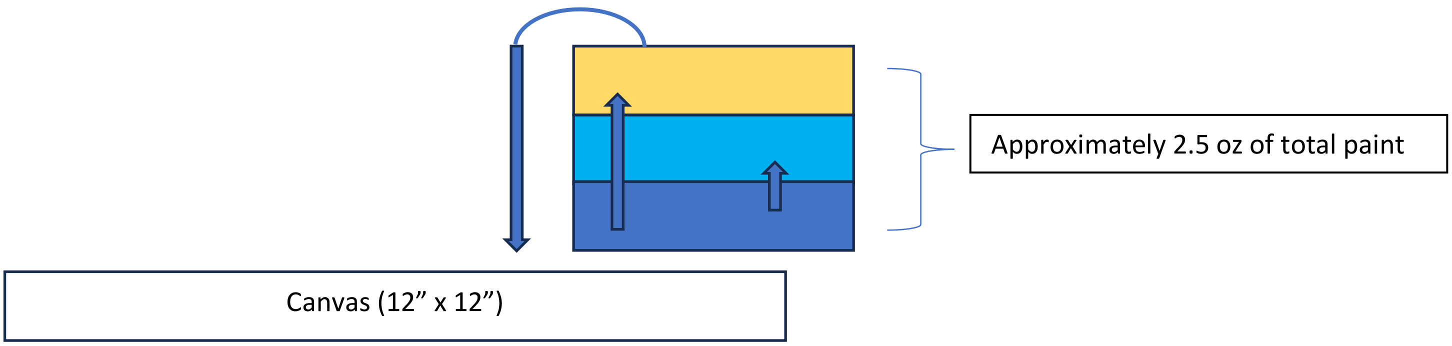


Figure 2, diagram of flow visualization apparatus.

Figure 3, paint layered in the cup.

As seen above, the acrylic paint was stacked in a cup then poured onto a 12” x 12” canvas. We used three colors in this experiment. The lighter the color, the less dense the fluid. The darker the color, the denser the fluid was. We opted to pour the darkest color on the bottom, and the lightest color on the top. We flipped the cup onto the canvas. The densest color sunk down, which caused the less dense color to rise to the surface, and therefore mixture occurred. This mixture process is known as the Rayleigh-Taylor instability. When the density of one paint is less than another, the viscous layer becomes unstable. This hydrodynamic instability causes the fluids to accelerate into each other. The pattern in figured one was discovered by Siqueiros in the 1930’s [2]. The Rayleigh-Taylor instability has been further studied on a larger scale in geodynamics. The concept causes the growth of mantle plumes, creates salt dynamics, and forms intraplate orogeny [3]. Plumes can originate at different geodynamic locations in the Earth’s mantle. Each layer of the mantle (D”, Transition, Mid oceanic ridge, Subduction zone) has a different density, hence the Rayleigh-Taylor instability. For salt dynamics, salt domes have less dense evaporative beds, which overlay the denser sediment rock strata. For intraplate orogeny, delamination and subsequent Rayleigh-Taylor instability occurs within the sub-continental lithospheric mantle.

**Reynolds Number Equation**

The team had to pour the paint in the cup slowly in order not to create mixture through turbulent flow. Therefore, our assumption for Reynolds number was less than 2300, which is laminar flow. The following equation was used to solve for Reynolds number of the lightest paint:

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

where $\rho$ is the density of the fluid, v is the velocity of the fluid, L is the length, and n is the dynamic viscosity of the fluid. Using a density of 1.3 g/cm^3 [4], a velocity of 8 cm/s, a length of 11 cm, and a dynamic viscosity of 1.55 Pa * S according to manufacturer notes.  Reynolds number can be calculated to be 720.16. This was the expected value as this falls below the threshold of 2300 to be recognized as laminar flow.

## Experiment Setup

Figure 4, experimental setup.

We shot a series of photographs outside the engineering center. It was shot around noon so there was plenty of natural light for our image. We used three different colors that created enough contrast to show off the Rayleigh-Taylor instability. The original cup we filled with paint was very tall, so we cut it in half in order to prevent turbulent flow of the paint dropping a longer length. A plastic cover was placed on the exterior in order to prevent paint splashing and creating a mess.

The following camera settings were used on the Canon EOS Rebel T3I

1/60, f/5.0, 42.0 mm, 100 iso

We used a high shutter speed of 1/60. A low shutter speed would have allowed for more light to enter the image, but this wasn’t necessary as it was taken outside during the day. The picture was taken approximately 15 cm from the mixed paint. A 42 mm zoom lens and 5.0 aperture were used for this specific image. Finally, a low iso of 100 was used to create a lower sensitivity to the light.

## Image processing

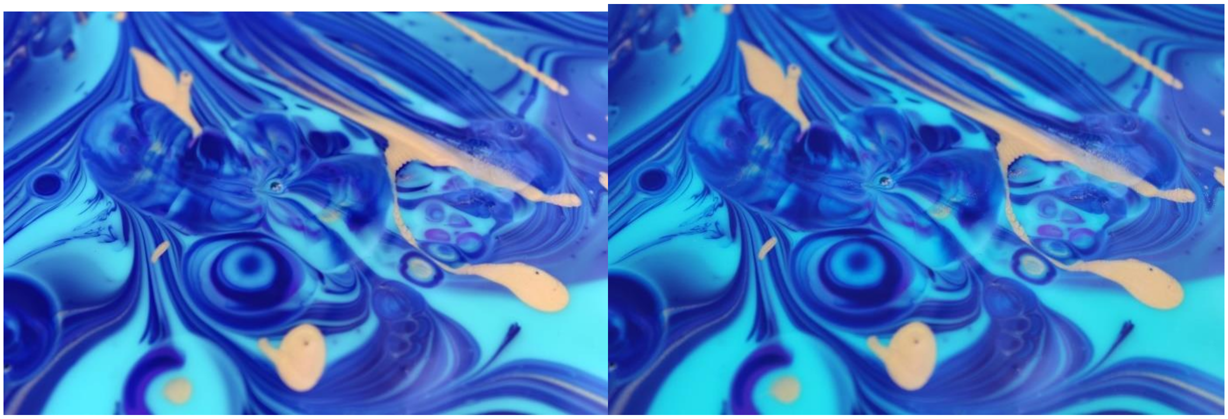

Figure 4, after editing (Left), before editing (Right)

Dark Table was the editing software used to process my original image. Some notable edits to the image were increasing the sharpness. This helped the circular waves stand out more. I also played with the white balance and local contrast to make the colors appear more vivid. Lens correction caused a slight zoom as well that helped capture a “closer” image. I also did some color correction to make the blue colors stand out more. Overall, I believe my editing helped create a color contrast and sharpened the image without taking away from the picture.

## Conclusion:

Overall, the team was able to capture Rayleigh-Taylor instability using acrylic paint. I believe I was able to capture an aesthetically pleasing image, while also showing the physics occurring between the different paint colors. Another approach to this image to make it more aesthetically pleasing would be to incorporate a lot more colors. For simplicity however, we thought that three colors were aesthetic enough while also showing the physics occurring.

References

[1] Hertzberg, Jean. "SYLLABUS MCEN 4151/5151/ FILM 4200/ ARTF 5200/ ATLS 4151/5151 Flow Visualization: The Physics and Art of Fluid Flow Fall 2023." FLOW VISUALIZATION A Course in the Physics and Art of Fluid Flow, 23 Aug. 2023, https://www.flowvis.org/wp/content/uploads/2023/08/syllabusF23.pdf.

[2] de la Calleja, Elsa M., et al. "Rayleigh-Taylor Instability Creates Provocative Images in Painting." AIP Publishing, AIP Publishing, 19 Sept. 2014, pubs.aip.org/aip/pof/article/26/9/091102/314787/Rayleigh-Taylor-instability-creates-provocative.

[3] Biswas, Uddalak. "Rayleigh-Taylor Instability in Geodynamics." Geodynamics, 23 Feb. 2021, blogs.egu.eu/divisions/gd/2021/02/17/rayleigh-taylor-instability-in-geodynamics/.

[4] https://justpaint.org/pigment-density/