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Flow Visualization

November 11, 2024

Team Third - Coffee and Cream

Introduction

For this project Pablo Botin and I were trying to get a clear image of coffee creamer being dispersed in coffee when it is first poured in. The picture shows the aftermath of the Rayleigh-Taylor Instability. I ended up really liking that we went with coffee and creamer rather than two drastically different as I quite like the difference in the color of the swirls and the dark coffee base being more subtle. The only thing I would have done differently was adding another picture from a side angle although I appreciate the picture I have as a standalone photo.

Mechanics and Setup

The setup for this photo was very simple. Pablo and I used a small glass bowl filled with normal black coffee. Then one of us would pour in a small amount of the creamer and stir it while the other shoots. His desk worked well as a backdrop as it was a nice dark brown. When the cream is first poured in it sinks to the bottom then rises to the top of the coffee. This is due to the Rayleigh-Taylor Instability. This is a fluid flow phenomenon that occurs when a fluid pushes on another denser fluid. Many people know about how oil sits on top of water because it is less dense but the Rayleigh-Taylor Instability explains what happens when water is on top of oil. Due to gravity, the

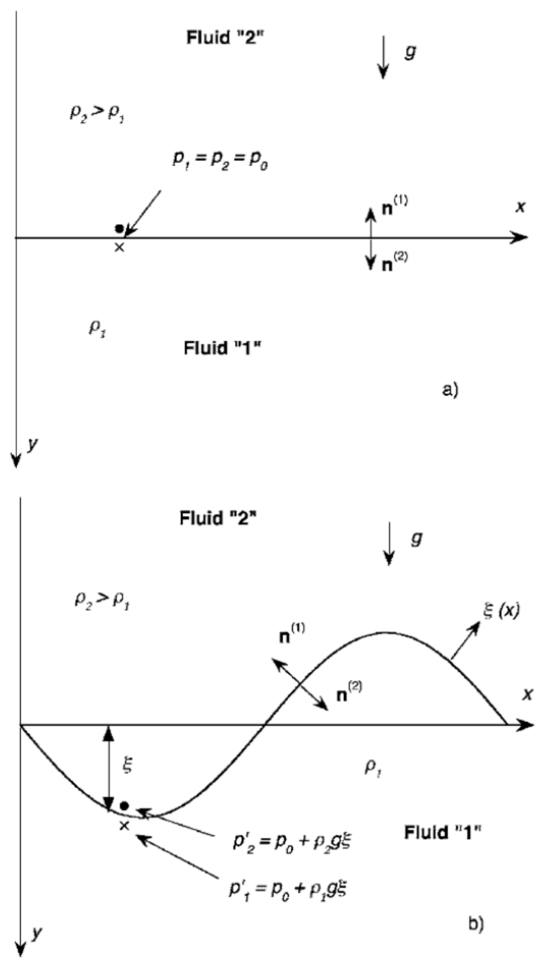

Figure 1 (Piriz, 2006)

water will sink and the oil will float however they are both incompressible fluids so the surface where the oil and water meet will start to deform, shown in figure 1, and the result are plumes from the fluids until it eventually stabilizes. Interestingly, this is the same instability that creates the infamous mushroom cloud. There is an important dimensionless number that is used in analyzing this phenomenon called the Atwood number:

$$A_T = \frac{\rho_1 - \rho_2}{\rho_1 + rho_2}$$

$$\sqrt{kgA_T}$$

$$k = Wavenumber$$

$$g = Gravity$$

The stability of the two fluids is directly proportional to the second equation. (Suchandra, 2023) This makes sense because if the difference in densities is lower it will be more stable. However, stability is also proportional to the wavenumber showing that even if the fluid on the bottom is much less dense than the fluid on the top, if the surface tension conditions are strong enough then it will still be a stable system.

Photography

The biggest issue I ran into while trying to capture this image was the glare from the light as well as the reflection in the coffee. Getting this shot ended up being a trial and error process with the ISO and the shutter speed. It was always either way too dark or showed to much glare. For this picture I used the Canon EOS Rebel XS with a EF-S 18-55mm lens. The settings that I landed on for this shot was an ISO of 800 and a shutter speed of 1/50s.

I was happy with how the picture turned out. One thing I like about it is that it almost reminds me of a photo of a planet from orbit. Then when I was researching this topic I found someone making a direct comparison of how putting cream in coffee can look like a nebula because you can observe this instability in many different gases in space. Although I am satisfied with my image, if I did this project again I would have used a narrower container and shot from the side as I would have loved to get a clear shot of the initial plume from the instability. I also think it would be very interesting to try out a bunch of different liquids just to see how much the difference densities change aspects of the instability.

References

P, A, et al. "The Rayleigh-Taylor Instability." *American Journal of Physics*, vol. 74, no. 12, 1 Dec. 2006.

Suchandra, Parsoon, and Davesh Ranjan. "Dynamics of multilayer Rayleigh–Taylor instability at moderately high Atwood numbers." *Journal of Fluid Mechanics*, vol. 974, 3 Nov. 2023.