Team First
Capturing Turbulence: Heavy Cream in Coffee
Izzy Young

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1 BACKGROUND

This image is representative of part of a video that was taken on September 24, 2023. The intention was to capture the turbulent flow that comes from mixing coffee and heavy cream. The experiment was done in collaboration with Avery Fails, Sarah Hartin, and Monica Luebke. We attempted whole milk, oat milk, almond milk, and heavy cream. The results ended up being similar in some ways but different in others. This report will review how the heavy cream video was captured.

2 EXPERIMENTAL SETUP

This experiment was set up at the ITLL at the University of Colorado Boulder. Using a ledge in the ITLL, we set up a white back drop and placed a clear class against the corner of the ledge. The camera was setup on a tripod and turned vertically to capture the maximum flow. Next, brewed Starbucks Tribute Blend was added to the clear glass. The coffee brand used can be seen in Figure 1.

Figure 1: The coffee brand used to brew the coffee for this experiment.

Once the coffee was poured and the tripod set up, the setup appeared as in figure 2.

Figure 2: Camera and tripod setup with coffee in its clear glass.

After a few practice shots, we decided a background was needed to prevent reflections on the clear glass coming from the lighting of the building. Utilizing discarded research posters' white backing to block reflections, we were able to capture an image with minimal distractions. Our setup is shown in figure 3.

Figure 3: Research papers being used to block light from reflections from blocking the clear glass.

Once the coffee was setup, I recorded the video and poured heavy cream into the coffee from about ten inches above the top of the coffee line. The heavy cream used can be seen in figure 4. A diagram of the coffee setup can be seen in figure 5.

Figure 4: Heavy cream used in the experiment.

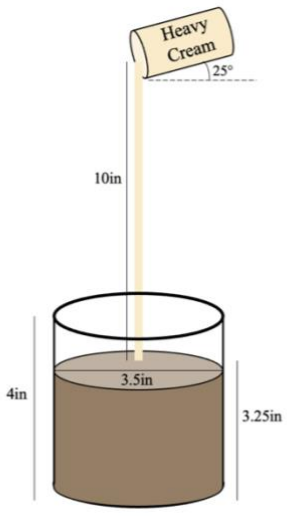

Figure 5: Diagram of the coffee setup and the cold heavy cream pour.

3 PHYSICS OF THE FLOW

This video shows cold heavy cream being poured into hot coffee. The flow leaving the container of heavy cream can be described as laminar flow. When the cream hits the coffee, the flow becomes transitional flow, and many convective currents are created. As more and more coffee is added, the coffee and heavy cream mix and fully become one mixture that is a caramel color.

To calculate the Reynolds number of the poured coffee, the diameter of the flow was utilized. The equation for Reynolds number is in equation 1.

$$Re = \frac{\rho V D}{\mu} \qquad \text{[Equation 1]}$$

The density in this instance is 0.994 kg/L or 994 kg/m^3. [2] The viscosity is 0.014 Pa-s [3]. The diameter of the fluid pour was about 0.00635m and the velocity was 0.254 m/s. Once these values are plugged into Equation 1, we find that Reynolds number is 114.52. Since this is significantly less than the boundary for laminar versus turbulent flow, the flow can be categorized as laminar flow.

Once the flow hits the coffee, these variables change. The density of the coffee mixed with heavy cream is about 999 kg/m3. This is an average of seventy percent coffee's density [4] and thirty percent heavy cream's density. The viscosity was calculated the same way as the density and is about .0112 Pa-s. The velocity remains constant as it hits the coffee and the diameter changes to 0.0889m (3.5in). After the calculation, I found that the Reynolds number is 2014. This puts the coffee in the transition phase. This makes sense because the still coffee *transitions* into more turbulent flow.

4 VISUALIZATION AND PHOTOGRAPHY TECHNIQUES

This photo was taken using marked boundary techniques [1]. Clearly, the heavy cream separates the black coffee and creates a marked boundary. The separation is quite a beautiful video and a stunning representation of the physics flow.

One of the key factors in capturing this photo was lighting. We used natural lighting and to capture the coffee in the best way. A focused light would reflect against the glass distract from the rest of the image. The physics would not be as clear with a focused light. Darkness would also be unsuccessful.

To highlight the flow better, I raised the contrast. I also increased the brightness. Additionally, I added a slow-motion portion to the video to really show the heavy cream hitting the coffee. The video was slowed down to 0.2 times speed.

The camera was about a foot away from the glass when the video was taken. The video was taken with an AF-P Nikkor 18-55mm lens of Nikon D5500 camera with a focal length of 55mm. The ISO was set to 200, the F-Stop as f/5.6, and the exposure as 1/10. The image shown at the top of this report is 1022pixels by 682 pixels. The aspect ratio was 1:3.5-5.6 G.

5 CONCLUSION

Using boundary techniques and natural lighting, a beautiful video was captured. It shows the laminar to transition flow of the heavy cream being added to the coffee. I really enjoy the way that this video turned out. The beauty in such an everyday task is beautiful.

5 Acknowledgments

This video was captured with assistance from Avery Fails, Sarah Hartin, and Monica Luebke. On the video, the music is royalty free, the song is titled “Here” by extenz.

7 REFERENCES

[1] Hertzberg, Jean. “Flow Vis Guidebook.” *Flow Visualization*, 13 July 2023, www.flowvis.org/Flow%20Vis%20Guide/overview-3-lighting/.

[2] Elert, Glenn. “Density of Milk.” *Density of Milk - The Physics Factbook*, hypertextbook.com/facts/2002/AliciaNoelleJones.shtml. Accessed 6 Oct. 2023.

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[4] “Density of Beverages, Coffee, Brewed, Espresso, Restaurant-Prepared.” *Density of Beverages, Coffee, Brewed, Espresso, Restaurant-Prepared*, www.aqua-calc.com/page/density-table/substance/beverages-coma-and-blank-coffee-coma-and-blank-brewed-coma-and-blank-espresso-coma-and-blank-restaurant-prepared. Accessed 6 Oct. 2023.