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Image-Vid 1

Coffee Creamer Flow

1. **Purpose**: As someone who brews coffee from scratch every day, I love the raw process from whole beans, to grounds, to black coffee and all the interesting physical changes in between. One of the more beautiful aspects of caffeinated drinks though is the addition of dairy and the variety of ways it can be introduced. Incredibly talented individuals can use precise knowledge of fluid flow to create artistic latte art on the surface of espresso, but for me the simple flow of creamer at the edges of the glass is enough to entice me. My project was to capture the flow of cold half and half creamer as it was poured into hot black coffee. I have seen the wonderfully contrasted flow on many advertisements but wanted to photograph this myself and see all stages of the process.

2. **Flow Apparatus and Discussion:** For this experiment, I placed one glass mason jar onto a piece of white posterboard on a kitchen table. The mason jar measures 5.25" tall and 3" in diameter. From figure 2 and figure 3 below, the jar was placed in the center of the posterboard, and the camera was perfectly level with the jar. I had 3 different light sources to illuminate the background and jar, so the fluid flow was clearly visible and had good contrast. I then poured the cold creamer into the jar containing the hot, black coffee and initially the creamer flowed to the bottom, partly due to gravity but also due to its colder temperature and larger density.

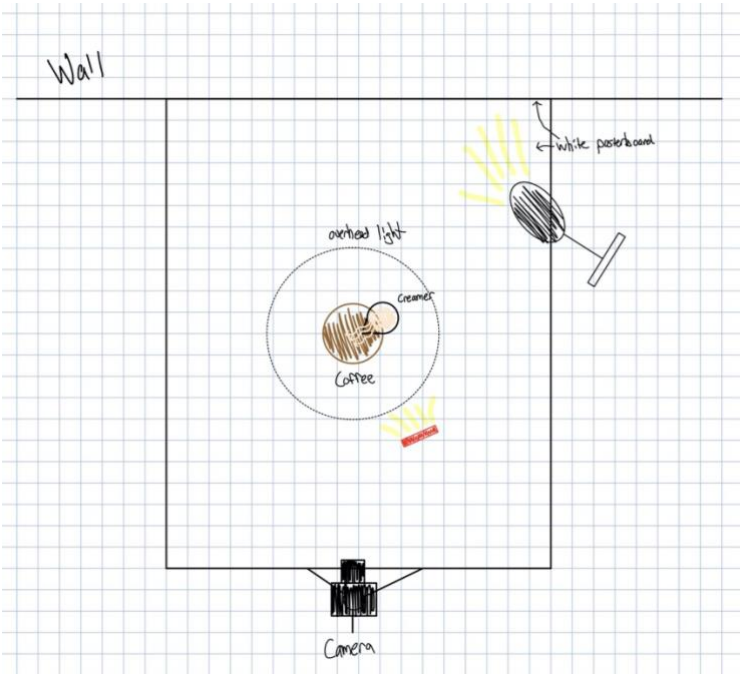

Figure 2: Overhead layout of subject and lighting

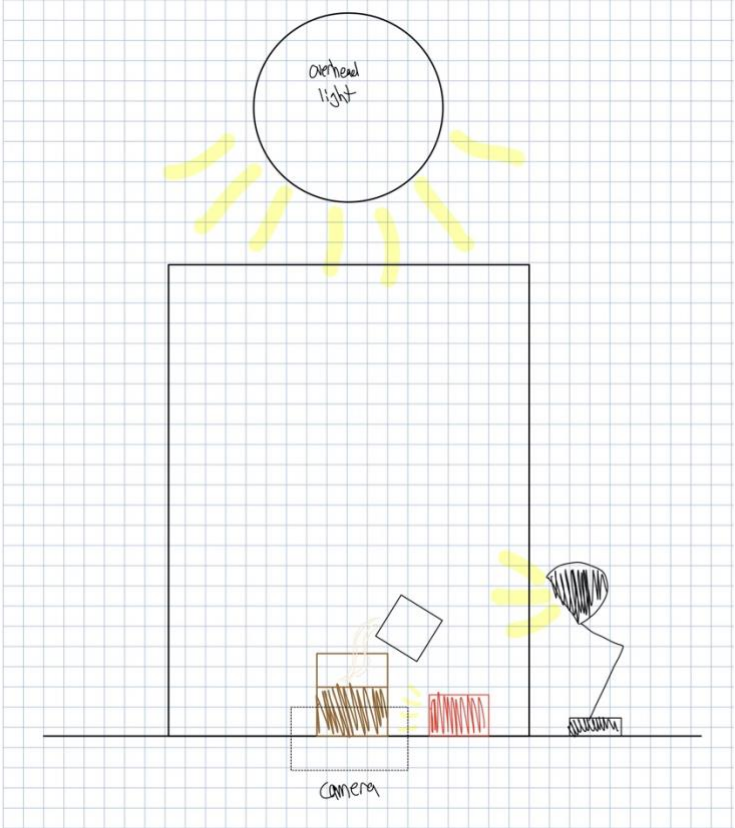

Figure 3: Camera perspective of subject and lighting

There are various fluid phenomena and ways to classify flow, and for this experiment the Reynolds number will be used. The Reynolds number is "the ratio of inertial forces to viscous forces…The Reynolds number is used to determine whether a fluid is in laminar or turbulent flow." [1]. To solve for the Reynold's number, I used the equation below. The d value was derived by measuring the distance one section of creamer flow had traveled between two photos, then the U value was determined by multiplying that value by 10 as each photo was taken .1 seconds apart. The v value used was the kinematic viscosity of water at 60 degrees C as an approximation for this value for coffee [3]. With these values, the Reynolds number for the coffee-creamer mixture at the transition point in the jar was 21.7, as shown in Equation 1 below. This is a relatively low Reynolds number meaning that the flow at this stage was laminar, as any value below 2000 would be [2]. Being unable to capture data from the flow within the jar that is not visible from the outside glass, it can be concluded that the flow of creamer within the coffee was faster during the initial pour and as it hit the bottom of the jar. With this assumption and

the previous Reynolds number calculation, one could reason that the flow was mostly laminar within the jar and may have become turbulent as it flowed outward from the center at the bottom of the jar. This experiment is a good visual representation of how laminar flow can become turbulent when the direction of the flow is impeded and then return to laminar flow when there is enough space for it to spread out within.

$$R_e = \frac{Ud}{v} = \frac{.01016\frac{m}{s} * .001016m}{4.75 * 10^{-6}\frac{m^2}{s}} = 21.7$$

Equation 1

3. **Visualization:** For this liquid fluid flow image, I used La Resistencia coffee beans from Espy, a small coffee roastery based in Ann Arbor, MI and Kroger half and half creamer. I brewed 340g of black coffee and poured that into the mason jar shown in the image. I then took the half and half out of the fridge and poured about 50ml into a measuring cup. I then had an assistant pour the creamer into the mason jar as I took photos at a high burst rate, 10 photos per second. For the setup of this scene, I placed two large white poster boards on my kitchen table, one flat on the table and one perpendicular against the wall to be used as the background. To light this, I had several sources of lighting in different areas. From above I had a spherical lantern light with a 60W white LED bulb, to light up the white background I used my desk lamp with the same style bulb, and finally I used the Aputure AL-MX very close to the coffee to brighten the face of the jar, so the flow was more defined.
4. **Photographic Technique:** The coffee was then placed on the white posterboard, and my tripod was placed about 2ft away from the jar. On this tripod I had my Sony A7iii with a Tamron 28-75mm f2.8 lens that was set to 62mm. This focal length provided the perfect perspective that had the jar as a large subject in the center of the frame, the measuring cup just slightly within it, and the entire background was solid white. For the camera settings, I wanted to make sure a lot of the jar was in focus, so I began with f8 then adjusted my shutter speed to 1/200 to make sure I captured the flow without any motion blur. I then had to raise my ISO to 1600 to properly expose the image. This original photo

was 24mp and 6000 x 4000 pixels but was then cropped down to 5097 x 3398. All my post processing was done in Lightroom, where I first adjusted the white balance, exposure, contrast, highlights, shadows, whites, and blacks. I used the tone curve to slightly adjust the highlights to be less harsh and raise the blacks to have the coffee appear more visible. I slightly raised the saturation of the oranges and yellows to have the coffee be more vibrant and lowered blue to have the background become slightly more even in whiteness. I also added radial filters placed over the creamer flow to increase the contrast and sharpness slightly to add to the definition and separation between it and the coffee itself. Lastly, I used the spot removal tool to eliminate any dust on the background as well as eliminating the horizon line between the two pieces of posterboard to create a more uniform image.

Photographic Details Overview

- **Object Distance:** 2 feet
- **Lens:** Tamron 28-75mm f2.8 set at 62mm
- **Camera:** Sony A7iii
- **Resolution:** 6000 x 4000 raw – 5097 x 3398 final
- **Aperture:** f8
- **Shutter Speed:** 1/200
- **ISO:** 1600

Figure 4: RAW Image

Figure 5: Raw Image vs Final Image

5. **Self-Assessment:** This image reveals that when it comes to fluid flow, even in everyday occurrences, a lot can happen in a short amount of time. The complex interactions that occur between two simple liquids is great entryway into the physical phenomena that they present here. Minute changes such as liquid temperatures, densities, ratios, and more can change every aspect of how fluids behave together showing that even a cup of coffee can lead one down a great scientific journey. What I like most about this image is the stark contrast between the pure white background and the dark earthy tones of the coffee and creamer mixture. Even further is the contrast between the creamer and the coffee itself split into two halves in this instance almost representing a "yin and yang" moment. One thing I dislike about this image is that defined flows and separation only mainly seen at the halfway point, I would have liked to have seen more of this flow present on the face of the glass to capture. For capturing the fluid physics, this does quite a good job at freezing the motion and clearly showing the two liquids interacting, even more so if one were to look at every photo in the set of burst shots. One of the things I am still curious about is how different types of milks would react and what physical properties they possess that cause these differences. To take this idea to another level and answer some of my questions, I could capture this same interaction, but change the milk type and temperature as well as change the coffee temperature, to see what combination produces the best fluid flow, artistic image, and of course the best tasting coffee.

References:

1. Bill Rehm, Drilling Consultant, Arash Haghshenas, Amir Saman Paknejad, Jerome Schubert, CHAPTER TWO - Situational Problems in MPD, Managed Pressure Drilling, Pages 39-80, (2008), https://doi.org/10.1016/B978-1-933762-24-1.50008-5.
2. E. Shashi Menon, Chapter Five - Fluid Flow in Pipes, Transmission Pipeline Calculations and Simulations Manual, Pages 149-234, (2015), https://doi.org/10.1016/B978-1-85617-830-3.00005-5.
3. Joseph Kestin, Mordechai Sokolov, and William A. Wakeham, “Viscosity of Liquid Water in the Range -8° C to 150° C,” J. Phys. Chem. Ref. Data, Vol 7, No. 3, Pages 941-948 (1978)