Team Third: Coffe Cream Dream

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For this experiment, I explored the interaction between coffee creamer and coffee to capture the turbulent flow patterns created as the creamer mixed into the coffee. Inspired by everyday observations of creamer cascading into coffee, I wanted to highlight this process's aesthetic and dynamic nature, emphasizing the turbulent pillars and fluid mixing zones. I aimed to create an image that showcased both the beauty and the complexity of these flows, revealing the underlying physics at play.

To set up the experiment, I used a square glass cup filled with 12 ounces of medium roast coffee as the primary fluid and French vanilla Coffee Mate creamer as the secondary fluid. The creamer was poured steadily from a height of 8 inches above the surface of the coffee. I aimed to keep the flow targeted at the center of the cup to ensure consistent interaction and minimize asymmetrical disturbances. The lighting setup consisted of overhead LED ceiling lights and a directly overhead oven hood light. I covered the nearby windows with blinds to eliminate reflections on the glass surface, ensuring a clean and distraction-free environment for photography.

I used a Sony a7R III camera paired with a Tamron 35-150mm lens to capture the experiment. The camera settings were an ISO of 3200, a zoom of 102mm, an aperture of f/4, and a shutter speed of 1/320 second. These settings were chosen to balance brightness, sharpness, and motion capture, allowing me to freeze the intricate flow patterns created by the mixing process. The camera was positioned to capture the side view of the glass, offering a clear perspective of the turbulent mixing as the creamer descended through the coffee.

The captured image highlights a range of distinct flow features. The primary focus is on the turbulent pillars of cream rising through the coffee, creating striking contrasts between the light, creamy regions, and the darker coffee. The creamer initially enters the coffee as a dense, smooth stream but rapidly breaks apart into a chaotic, pillar-like structure as it descends. These pillars exhibit a combination of laminar flow near the top and turbulence as they interact with the surrounding coffee.

The light brown to-black transition illustrates the diffusive mixing between the two fluids. As the creamer penetrates the coffee, the difference in density and momentum drives the creation of vortices and turbulent regions, leading to an intricate pattern of mixing. At the boundaries of these pillars, shear forces create rippling effects that further contribute to the aesthetic complexity of the flow. The overall result is a dynamic interplay of motion, density differences, and fluid entrainment.

The flow captured in the image presents a dynamic interaction between the coffee and the creamer, showcasing turbulence, entrainment, and mixing. As the creamer is poured from a height of 8 inches, it enters the coffee with enough velocity to displace the surrounding fluid, initiating a visually striking turbulent flow. This turbulence manifests as pillars of cream descending into the coffee and swirling as they mix with the denser liquid below. The flow demonstrates complex interactions where the creamer's velocity and the coffee's resistance create pressure differentials, leading to the observed spiraling patterns.

At the point of impact, the creamer creates localized turbulence, with kinetic energy dispersing through the coffee in radial patterns. As the lighter creamer moves downward, it generates shear forces at the interface where the two fluids meet, producing visible vortex structures and boundary layers. These vortices enhance the mixing process, drawing coffee upward into the cream-laden region while also pulling the creamer deeper into the cup. This interplay between the two fluids results in a visually captivating transition from lighter, cream-rich areas to darker coffee regions.

The interaction also highlights entrainment, as the descending cream entrains coffee along its path. This creates distinct columns where the flow transitions from smooth to turbulent. The observable "pillars" of cream are a direct result of the balance between gravitational forces pulling the creamer down and the viscous resistance of the coffee, which slows its descent. These pillars eventually broaden and dissipate, giving way to swirling patterns that are spread out more evenly through the liquid.

This experiment illustrates key fluid physics principles, such as drag, wake formation, and buoyancy-driven flows, all of which contribute to the final image's aesthetic and scientific intrigue.

To quantify the flow regime, I calculated the Reynolds number (Re) based on the experimental parameters:

- **Density of coffee (ρ):** 1000 kg/m³
- **Fluid velocity (v):** Estimated at 0.3048 m/s (1 ft/s)
- **Stream diameter (L):** Approximately 0.005 m
- **Dynamic viscosity of coffee (μ):** 0.001 Pa·s

$$Re = \frac{p \bullet v \bullet L}{\mu} = \frac{1000 \bullet 0.3048 \bullet 0.005}{0.001} = 1524$$

This Reynolds number indicates a transitional flow regime where both laminar and turbulent characteristics are present. This aligns with the observation of a smooth initial flow transitioning into turbulence as the creamer mixes with the coffee.

Camera Type	Mirrorless
Camera Model	Sony A7R3
Original Dimensions	5168 x 3448
Distance from Subject	18 Inches
Aperture	f4
Shutter Speed	1/320s

ISO	3200
Focal Length	102mm
Lens Specs	Tamron 35-150mm f2-2.8
FOV	● Hor: 19.96 degrees ● Vert 13.42 degrees
Post Processing	● Made black and white ● S to RGB curve ● Increased colors

To enhance the final image, I applied a series of post-processing adjustments. First, I converted the image to black and white to eliminate color distractions, ensuring the flow patterns took center stage. Next, I applied an S-curve in the RGB channel, which amplified contrast, making the bright areas of cream more luminous and the dark coffee tones deeper. Finally, I enhanced the overall image clarity and tonal separation, focusing on making the swirling patterns of the creamer more visible and dramatic. These edits were made to draw the viewer's attention to the intricate turbulence and highlight the interaction between the cream and coffee.

Works Cited

Boundary Layer, https://www.grc.nasa.gov/www/k-12/BGP/boundlay.html. Accessed 3 December 2024.

"Laminar and Turbulent Boundary Layers." *MDP*, http://www-mdp.eng.cam.ac.uk/web/library/enginfo/aerothermal_dvd_only/aero/fprops/introvisc/node8.html. Accessed 3 December 2024.