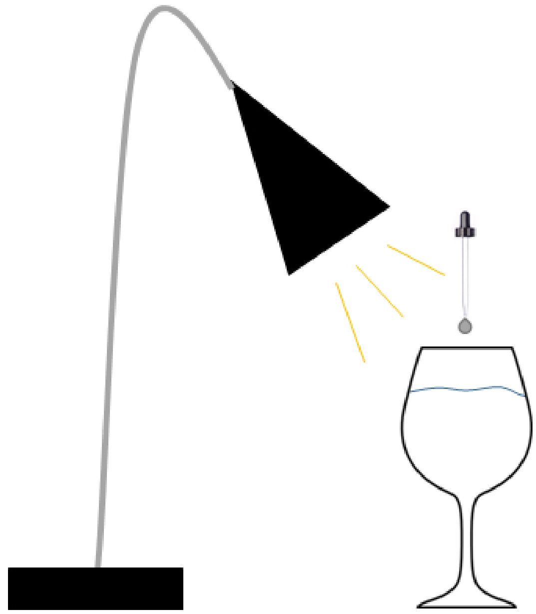
Final “Get Wet" Image: Cream Castle

1 Purpose

The purpose of this visualization was to capture the nature of whipping cream and the fluid dynamics that result from the billowing plumes that arise when it is dropped into a pool of water. The phenomena was initially observed by trying the experiment with cold whipping cream in warm water, which yielded interesting tower-like structures that would form out of a single drop. The shot was captured thanks to the help of my roommate, Allyssa, who dropped the cream into the water.

2 Apparatus

The apparatus used in the image was a wine glass filled with warm water at the highest temperature from the tap in my apartment, which falls in the range of 85°to 90°Fahrenheit. Bubbles that were going to appear at the foreground of the image were scraped from the inside of the glass, so as not to cause any focusing on the bubbles that would appear in front of the cream that would be dropped into the water. Then, a liquid dropper was filled with cold (kept in refrigerator at 40°F) Grade A ultra-pasteurized whipping cream, which contains approximately 35% fat. The water was allowed approximately 1 minute of settling time before dropper was held about an inch above the surface and a single drop was released. The visualization occurs approximately 20-25 seconds after the cream has been dropped and has had time to interact with the warm water. A diagram of the setup can be seen below.



Visualization setup

The fluid phenomenon occurring in the image is largely due to positive buoyancy, meaning that the entering fluid tends to rise. The result of the cream rising in the warm water is a visualized "plume" which is a column of one fluid rising through another, and is directly driven by buoyancy. In [1], Turner discusses the nature of this plume and how the cap of the flow moves at a slower rate than the column producing it, approximately 0.6 times the mean velocity of the columnar stream. This is significant for understanding why the cream accumulates at the top of each of the columns present in the flow, which can be attributed to its velocity in this case.

This positive buoyancy that is occurring between the liquids can also be attributed to several other fluid properties that were present in this setup. The first of these properties is density, which is different between the two fluids used. A general characteristic of the whipping cream is that it contains a significant amount of fat in it, which tends to rise. In most cases of milk preparation, this fat is "skimmed" from the top of a cream, hence the term "skimmed milk". This image is a direct account of this fat rising to the top of the wine glass and accumulating in an aesthetically pleasing spiral form. [3] discusses the aggregation of more fat globules with increasing temperature as well, meaning that more fat builds up at warmer temperatures, thus increasing the buoyancy effects prevalent in the fluid. The fluid properties for water and whipping cream are listed in Table 1 below.

	Water	Heavy cream
Density (kg/m^3)	1000	994

Table 1: Fluid properties of water and cream

Aside from simply having different densities at room temperature, the fact that the water was relatively hot also seems to increase the forcing effect of the fluid flow. These thermal forcing effects caused the reaction in the cream to happen a lot quicker than it would have in cold water. Later, the same experiment was attempted with cold water, which actually yielded less dramatic results (relatively slow movement and less columnar structures) since the similar temperatures did not cause any rapid forcing to occur in the cream. These reactions are due to the dependence of density on temperature. It was found that density does, in fact, change the flow scenario since the particles in the warmer liquid will move farther apart from each other and at a more rapid rate, as discussed by [2].

The Reynolds number is a quantity of interest in this flow, to further understand the flow pattern at hand. The calculation for the Reynolds number is shown below, where the velocity of the flow was calculated based on the time a previous image of the flow was taken. To do this, the distance of the flow from the bottom of the 4.5" tall wine glass was compared to an average of where the flow appears in the final shot, which occurs 19 seconds later. This calculation for velocity in the y-direction is also shown below:

$$\begin{aligned} v_y &= \frac{\delta x}{t} \\ &= \frac{0.0134m}{19s} \\ &= \mathbf{0.00070\ m/s} \end{aligned}$$

$$\begin{aligned} Re &= \frac{\rho v L}{\mu} \\ &= \frac{(994\frac{kg}{m^3})(0.0007\frac{m}{s})(0.0021m)}{0.00289Pa * s} \\ &= \mathbf{0.51} \end{aligned}$$

3 Visualization Techniques

The visualization technique used is known as a seeded boundary, meaning the milky liquid is the seeding fluid, and the transparent water does not scatter or absorb any light which makes the seeding fluid more apparent. This causes a clear boundary to be visible, especially against the dark background that was utilized for this image.

The lighting used was a spotlight lamp with a 4.5 Watt LED, which produces 200 lumens. The equivalent warmth for this light is 2700 Kelvin, which gives off a bright and relatively warm color. The lamp was placed with the mouth shining onto the top of the glass at a 45°angle from the vertical, and about 4 inches above the top of the glass as was shown previously in the diagram of the setup. The lamp can be seen in the upper left corner of the original image for reference in a later section. This was the only light source in the room, and all other lights in the surrounding area were turned off.

4 Photographic Techniques

The setup was approximately 6 inches away from the camera lens, while the focal length was 4.3 inches. The digital camera that was used to perform this visualization is a Canon PowerShot SX520 HS, with a focal length of 4.3-180.6mm, aperture 1:3.4-6.0. The settings used to capture the image are as follows:

- Shutter speed 1/60
- f/5.6
- ISO 800

The original image size was 4608x3456 pixels, while the final was 4320x3456 pixels. GIMP was used as the choice of image editing software, where post processing was performed to darken the black background behind the flow, and enhance the whites in the cream. This was achieved using the Curves feature by creating an "S" shaped curve. Also, the background of the original image has a piece of white paper as well as a visible spotlight that was edited out with the Paint tool by coloring over those features with black paint. Layers were also utilized to mirror the upper right corner of the wine glass onto the upper left side to eliminate the washed out corner from the bright LED light that was incident on that corner. Some cleaning up was done using the Dodge/Burn tool, which selectively brightens or darkens the area onto which the tool is applied, to cleanly blend this addition into the image. The original image is displayed below.

Original Image

5 Image Thoughts

This image reveals the beauty of fluid physics in a very clear way. With a very simple combination of fluids, an aesthetically pleasing image is realized. I like the focus on the fluid phenomena that is happening, as well as the swirl occuring at the top of the image due to the accumulation of the fat in the cream. I also think that the bubbles add a nice touch to the feeling of the fluid being enclosed in the wine glass in an otherwise dark place. In the future I might attempt to dilute the lighting so as not to produce such a strong reflection in the glass. I attempted to edit the reflections out of the image, but it proved too difficult to achieve with my level of image editing capabilities. With that being said, I believe that I realized my intent with this image, by capturing the suspended milk in water very clearly and without altering any of the information associated with the fluid flow that is occurring. If I were to develop this idea further, I would choose to observe creams of different fat contents, since heavier creams might tend to produce larger positive buoyancy reactions and perhaps larger plumes. Another development could involve changing the temperature of the water and observing where the threshold of this thermal forcing truly occurs.

References

[1] J. S. Turner *The 'starting plume' in neutral surroundings.* Journal of Fluid Mechanics, 13, pp 356-368 doi:10.1017/S0022112062000762 (1962).

[2] R. J. Plaza *Sink or Swim: The Effects of Temperature on Liquid Density and Buoyancy.* 2006.

[3] Ihara K. et. al. *Influence of whipping temperature on the whipping properties and rheological characteristics of whipped cream.* 2010.