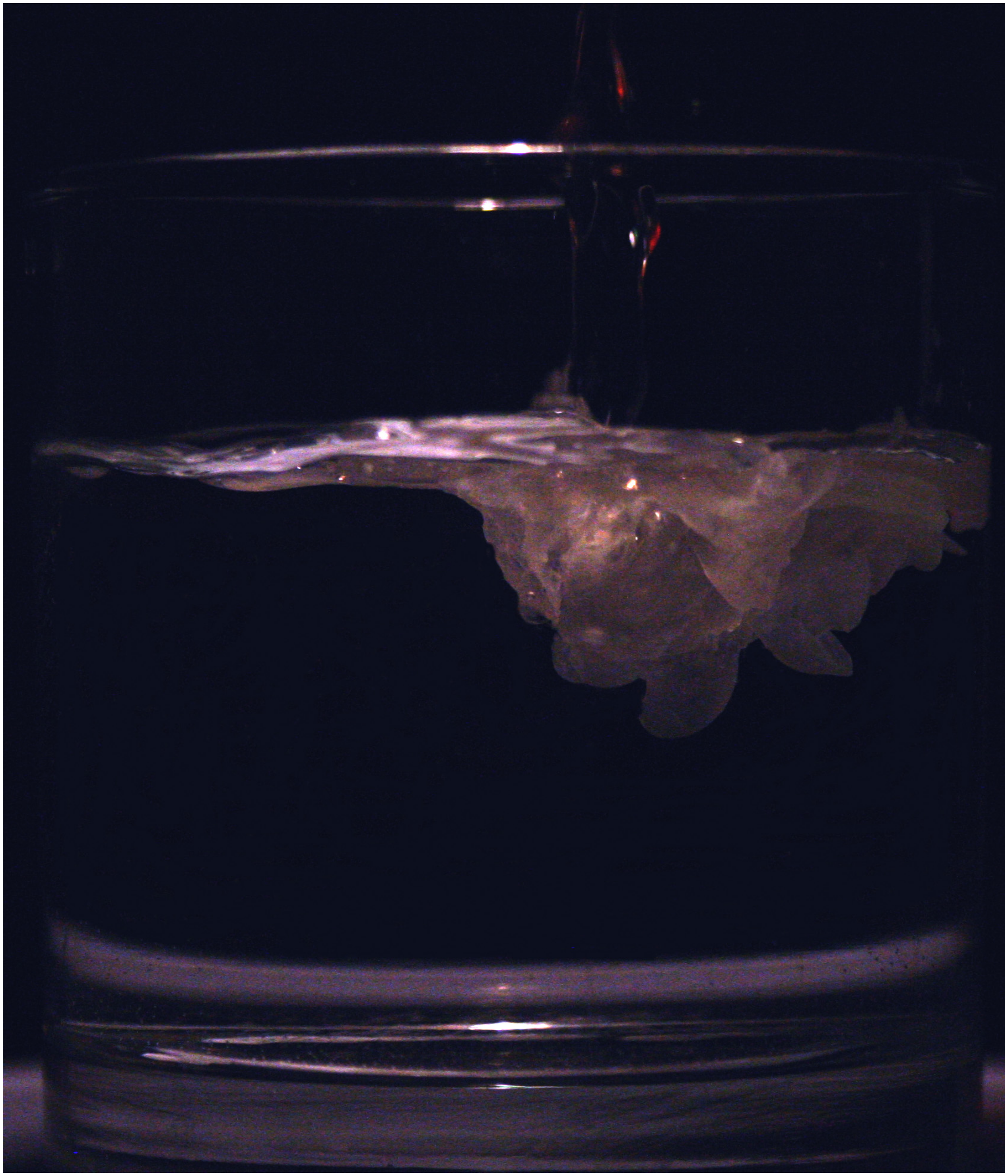
<u>Hot Wax Pouring into Cold Water</u>

Chip Fisher

3/11/09



Context of the Image

This image was captured for the third project of the semester, working independently from my group while I was at home. My intention was to capture the penetration distance of a hot, low density fluid falling into cold water as well as to produce an interesting and beautiful image. The hot fluid in this image is melted candle wax, so as the wax was flowing though the cold water it was solidifying into a semisolid mass. An approximate penetration distance can be measured using this image because the hot wax solidified almost instantly after contacting the water. However, wax is much less dense than water and floats on top, so the penetration distance was most likely affected by buoyancy forces.

Experimental Apparatus and Visualization Technique

This experiment in fluid imaging was run in my kitchen by melting a candle in the oven at 250 °F for about 10 minutes and cooling a glass of water in the refrigerator at 35 °F. Basically this image is showing the melted candle wax being poured and solidifying as it flows into the cold water. The glass is 4 inches tall and 3 inches in diameter and filled with 3 ¼ inches of cold water. A total of approximately 1.57 cubic inches of wax was poured into the glass but this image only depicts the first third of that volume, or 0.52 cubic inches. Figure 1 is a detailed sketch of the experimental apparatus used. Two bar stools held the camera and the object about 18 inches apart. A common 60 Watt reading lamp lit the object from approximately 6 inches above.

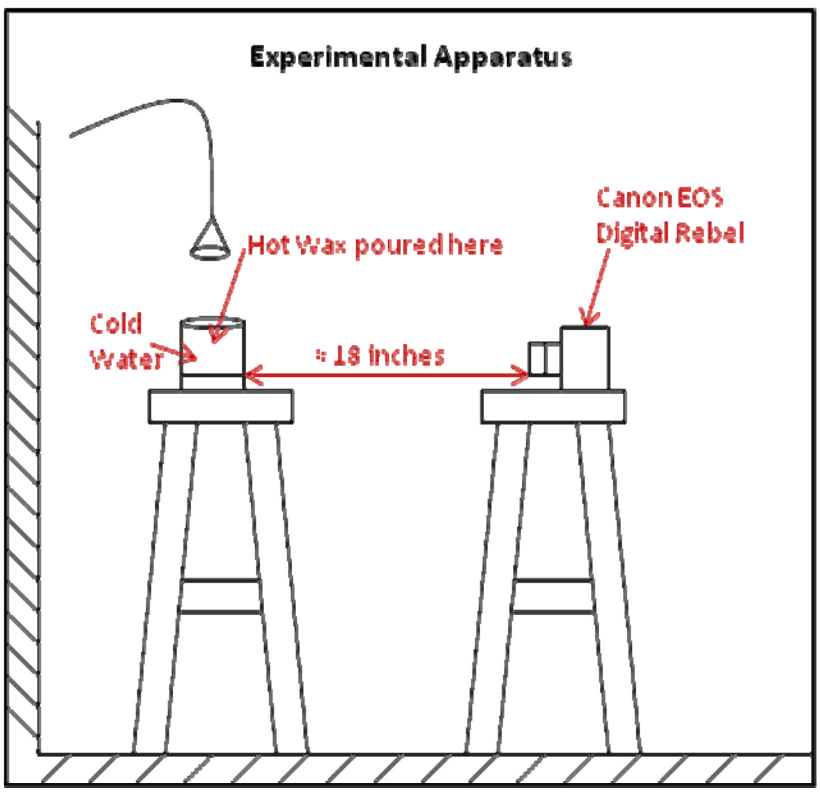


Figure 1. Experimental Apparatus

Since two fluids of varying density are mixing together, there is instability in the laminar flow. This was captured as the wax solidified in the cold water as the ripples and bulges in the iceberg-shaped mass of semi-solid candle wax. An appropriate dimensionless scale for this image would be the Atwood number, which compares the densities of two fluids mixing together, defined in Equation (1).

$$At = \rho_1 - \rho_2/(\rho_1 + \rho_2)\ , \ \text{where } \rho_1 > \rho_2 \qquad \textbf{(1)}$$

Assuming that solid candle wax has a density similar to that of ice and that the solidifying wax is more solid than liquid (but fluid nonetheless!), then the density of wax is approximately 0.917 g/mL and water is 1.000 g/mL [2]. The Atwood number for the image is then At = 0.0433. The Reynolds number could not b determined here with any reportable accuracy.

This image also depicts surface tension differences because candle wax is commonly made of paraffin, which is a long chain of carbon and hydrogen atoms, similar to the molecule shown in Figure 2 [1].

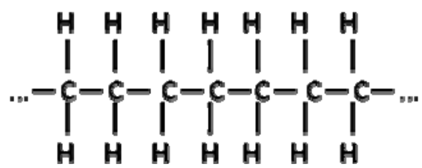


Figure 2. Typical molecular structure of paraffin, or candle, wax.

As the hot wax is mixing with the cold water, the hydrophobic effect also drives segregation of the wax and water phases. The density and hydrophobic interactions combine to generate the instabilities in the flow that are depicted in the image.

Photographic Technique

This image was captured using a Canon EOS Digital Rebel. The field of view in this image is essentially the height of the glass, 4 inches, and similar scale for the depth of field, 3 inches (the diameter of the glass). As shown in Figure 1, the camera was placed about 18 inches from the glass and held steady on a bar stool identical to the stool the glass. The camera specifications include a focal length of 66 mm and aperture value of f/4.9. The exposure was a 1/800 second shutter speed and ISO setting of 1600. Image dimension were 2961 x 1962 pixels (horizontal x vertical). The final image, and subject of this report, was edited in Adobe Photoshop using the Curves and Levels functions to increase light and dark contrast then increase the intensity of blue, respectively. The increased intensity of blue gives the image an icy, cool feel.

Conclusion

The image reveals phase changes and dynamic mixing, similar to cloud formation. Instead of air, water was used, and the "cloud" is made of semi-solid wax. What I like about this image is how the wax looks like those posters of icebergs, obviously on a much smaller scale. It also has that icy feel to it but with a sense of dormant warmth as a result of the top lighting—near the center of the image the wax appears to be glowing! What I don't like about the image is the pixilation, as a result of the high ISO setting. However, I wanted to capture falling wax without any motion blur so a very fast shutter speed was used. If I could redo the image, I would use one or more colored waxes and brighter lighting so that the ISO setting could be set low. To develop this idea further, I think mixing the wax in a non-polar liquid such as canola oil or olive oil could produce some very cool flows and images.

References

[1] Wikipedia Foundation, Inc. (2009, 3 10). *Wikipedia Free Encyclopedia*. Retrieved 11 2009, 3, from Paraffin: http://en.wikipedia.org/wiki/Paraffin

[2] Wikipedia Foundation, Inc. (2009, 3 11). *Wikipedia Free Encyclopedia*. Retrieved 11 2009, 3, from Ice: http://en.wikipedia.org/wiki/Ice