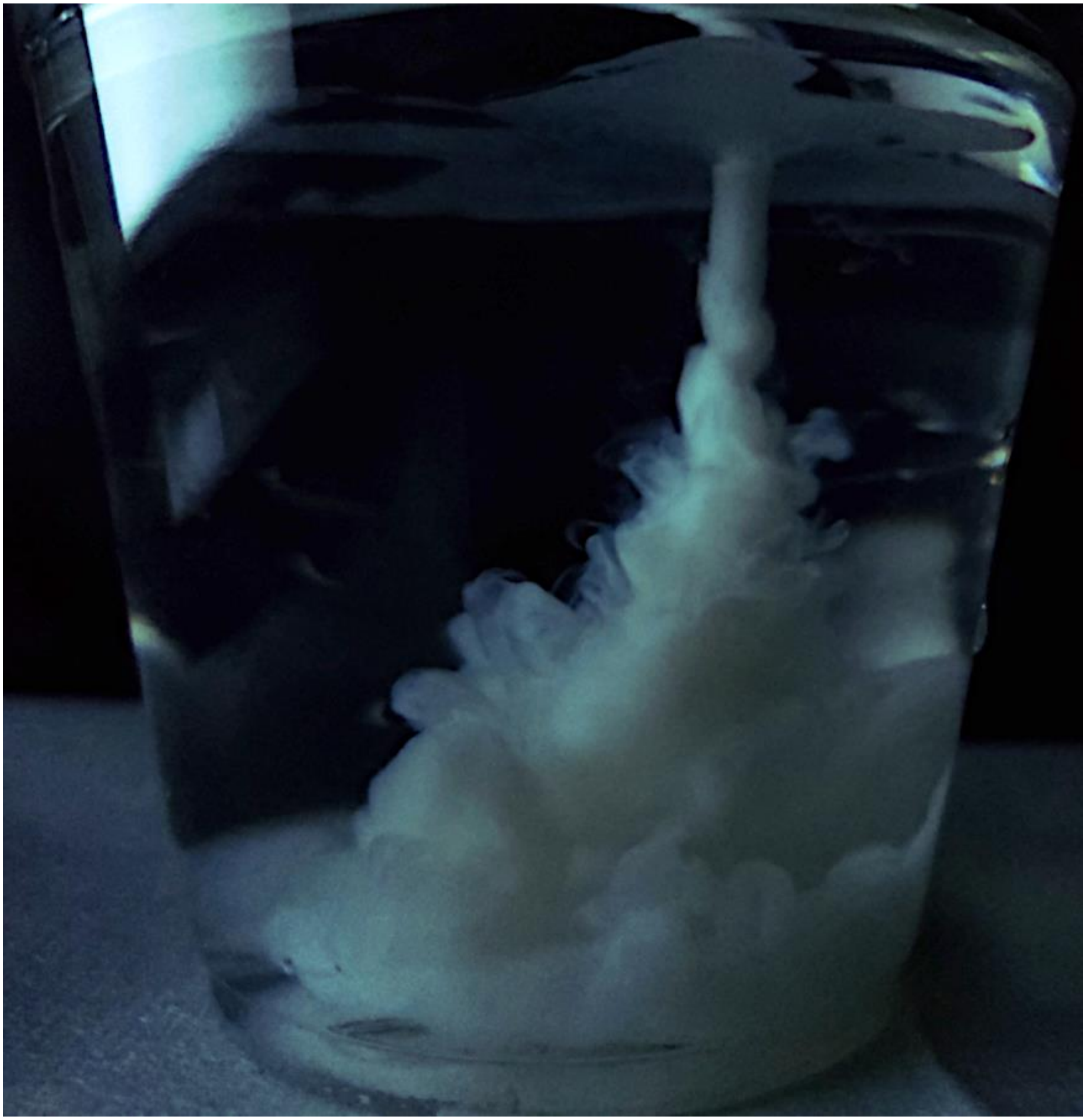
Flow of Milk in Water

Image-Video 1
MCEN 5151-001
University of Colorado Boulder
27 September 2020



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Introduction:

For the first image-video assignment, the purpose was to "get your feet wet" by taking a picture or video that demonstrates a phenomenon being observed and is a good picture or video. The phenomenon shown in this image is a visualization of milk in different mediums. In this case, milk is being poured from a cup into a glass of water. To visualize this phenomenon, a picture was taken to capture the turbulence of the milk when it contacted the surface of the water.

Physics and Flow:

The flow apparatus used in the image is demonstrated in figure 1. Two plastic cups were used to hold water and milk separately. The cup filled with water was filled to half an inch from the top and the milk was filled as needed until the right picture was taken.

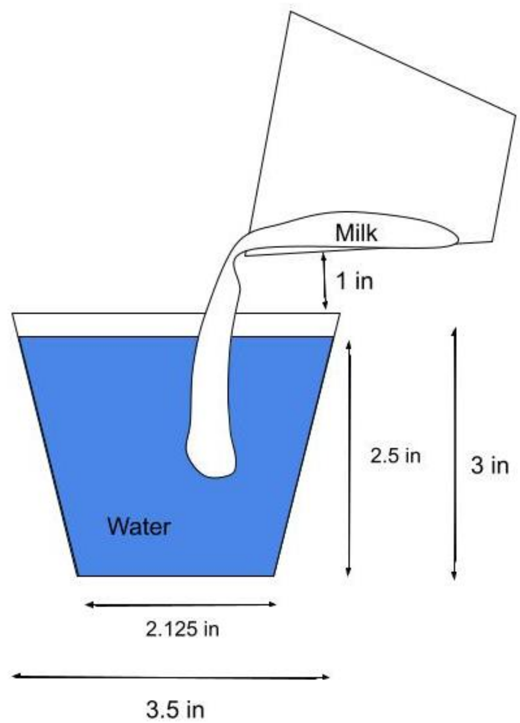

Figure 1: Sketch of Milk Poured into Water

The phenomenon occurring here is the transition from laminar to turbulent flow as the milk flows from air to water. Laminar flow and turbulent flow are also "referred to as streamline or viscous flow" and "characterized by the irregular movement of particles of the fluid". [4] The flow of the milk can be classified as laminar or turbulent using the Reynolds number which is defined as $Re = \frac{VL}{\mu}$. In the equation, Re is the Reynolds number, V is the velocity of the fluid flow, L is the characteristic length, and μ is the fluid viscosity. [1]

To find the Reynolds number, the fluid viscosity of milk and water must be determined. The kinematic viscosities of milk and water are $1.13 \times 10^{-6}\,\frac{m^2}{s}$ and $1.004 \times 10^{-6}\,\frac{m^2}{s}$ respectively. [2] The calculations for the Reynolds number of both fluids can be found in figure 2.

$$Re_{milk} = \frac{1.5\left(\frac{m}{s}\right) * .05(m)}{1.13 \times 10^{-6}\left(\frac{m^2}{s}\right)} = 66371$$

$$Re_{water} = \frac{1.5\left(\frac{m}{s}\right) * .05(m)}{1.004 \times 10^{-6}\,\frac{m^2}{s}} = 74701$$

Figure 2: Reynolds Number for Milk and Water

Because the Reynolds number of water is greater than the Reynolds number of milk, it would make sense for the milk to not completely reach turbulent flow as it contacts the surface of the water. The picture shows the milk have a laminar flow towards the top/surface and transition quickly to a turbulent flow.

The Rayleigh-Taylor instability is also a phenomenon that could be occurring in this photo. This is when the "instability of a heavy fluid layer [is] supported by a light one." [3] The main difference between this phenomenon and what is happening in the photo is that milk is denser than water, so the photo is the opposite of what the Rayleigh-Taylor instability is.

Visualization Technique:

The visualization technique used was mixing where 1% fat milk was poured onto tap water in Boulder, Colorado. The cups holding the milk and water were clear 9 oz plastic cups. The cups were placed onto white fabric and a black keyboard case was used as the background. Before taking a picture, the lights were completely off, and the photo was taken at night so no sunlight can interfere making the scenario pitch black. A laptop was used as the main light source by finding a video of a completely white screen and turning the brightness up to light the cups as much as possible. The laptop was placed to the left of the cup.

Photographic Technique:

One technique to consider was the size of the field of view. Considering that the cup was only a max of 3.5 inches in width and 3 inches in height, the field of view needed to be fairly small to cut out any distractions from the photo and make the milk the center of attention for viewers. To do this, the distance from the cup to the camera lens was very small at around 3 inches. Zooming in was not ideal because of how blurry the image looked. The camera used and its settings are as follows:

Camera:	Samsung Galaxy S9
Aperture:	f/1.5
Exposure:	1/250
Focal Length:	4 mm
ISO:	800
Width:	4032 pixels
Height:	3024 pixels

The type of camera was a phone camera because it was convenient and still had decent picture-taking capabilities. The aperture was set to f/1.5 to allow more exposure to light since the picture was being taken in the dark. Any light apart from the light from the computer gave the photo an unbalance in color, so all external lights were turned off. The exposure was set to 1/250 to capture the fast-moving milk in the water. The milk would quickly transition from laminar to turbulent flow, so a fast shutter speed would allow the flow to be visible and clear. The focal length was set to 4 mm to put the milk in focus. The ISO was set to 800 to allow more sensitivity to light to make the picture brighter. The laptop light was not as bright as I would have liked it to be, so a higher ISO solved the problem fairly well along with some brightening in post-processing. Lastly, the final image width and height were 4032 and 3024 pixels respectively. This width and height was the best setting for the Galaxy S9 because it allowed it to take a 12 MP picture which was the highest it was capable of.

In terms of post-processing, the brightness of the photo was made higher to see the lines of the milk better. The milk was also sharpened to make up for any blurriness and the color of the photo was adjusted so that the milk was clearer and more distinct in the water.

Conclusion:

The image showed a defined transition of milk from laminar to turbulent flow. The clear laminar flow towards the surface of the water was very interesting to me, and I thought it was very neat to see the milk cloud outwards as it hit the bottom of the cup of water. What caught my attention was the milk fat floating at the surface and separating from the milk itself. It goes to show how fat is less dense than water even though milk is slightly denser. Something I did not like about the image was the color choice. The color is not as vibrant as I would have liked it to be, so maybe next time I will add food dye to the milk or just make the photo black and white completely to make the milk the center of attention. I would have also liked to explore more phenomena that I could be missing in this image to fully understand what is going on.

References

[1] *Basics of Turbulent Flow* [PDF]. (n.d.). Cambridge: MIT. http://www.mit.edu/course/1/1.061/www/dream/SEVEN/SEVENTHEORY.PDF

[2] Edge, E. (n.d.). Kinematic Viscosity Table Chart of Liquids - Engineers Edge. Retrieved from https://www.engineersedge.com/fluid_flow/kinematic-viscosity-table.htm

[3] Kull, H. (2002, September 23). Theory of the Rayleigh-Taylor instability. Retrieved from https://www.sciencedirect.com/science/article/pii/037015739190153D

[4] Laminar and Turbulent Flow. (n.d.). Retrieved from https://engineeringlibrary.org/reference/laminar-and-turbulent-fluid-flow-doe-handbook

Appendix

Figure 3: Unedited Image