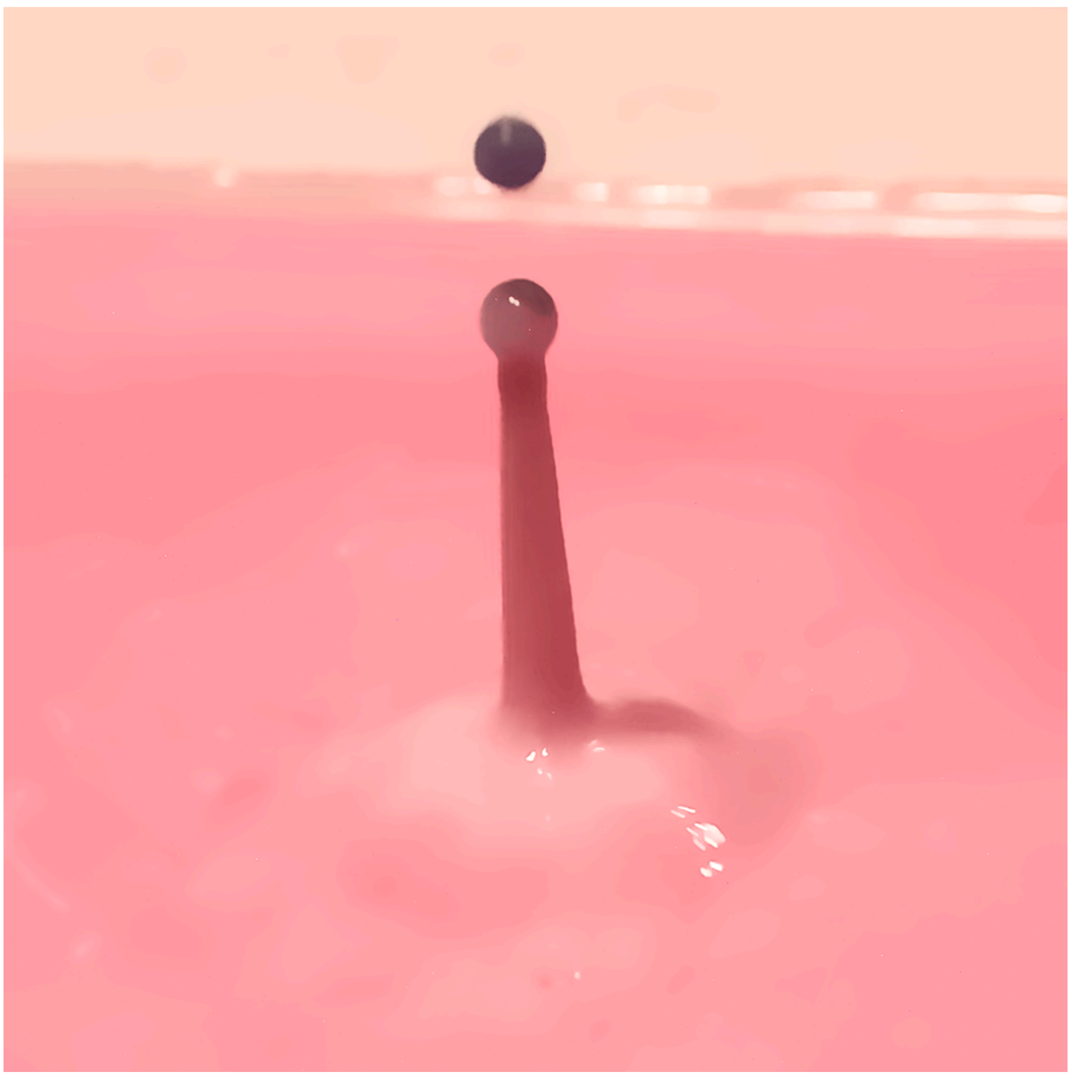
Hannah Brothers

Flow Visualization: Team Third

With help from Cort Sommer

MCEN 5151

November 21st, 2025



For the second third assignment of this course, I worked with Cort Sommer to capture droplets of liquid bouncing back from a surface of water. We originally intended to capture this to improve our photography skills for capturing fast-moving objects in higher resolution using just water. However, as we experimented, we examined the effects of different liquids bouncing back. The photo I have chosen is of a blue cornstarch and water slurry droplet bouncing back from a surface of water, dyed pink. The scientific intent of this photo was to capture the effect of liquid droplets bouncing back from a surface and the artistic intent was to improve our high-speed photography skills and capture a motion in time.

The set-up was created by filling a clear 8in x 8in Pyrex glass dish with 2 inches of water. A white backdrop was used behind the dish, with ceiling lighting from above. For each of our experiments, one of us took turns dropping drops of water or liquid from a pipette into the dish. We experimented with different heights, dyes, and cornstarch slurries. For my set-up, a cornstarch slurry was used and dyed blue. The water below was dyed pink from a previous experiment and was somewhat murky due to cornstarch sediment from earlier. The blue slurry was then released in droplets from approximately 1.5 feet from the water's surface. As droplets were released in succession, I took several photos and captured the one shown above, where the droplet is bouncing back from the surface. I estimate that the droplet captured is about 1 inch above the pink surface and is about 0.2 inches in diameter.

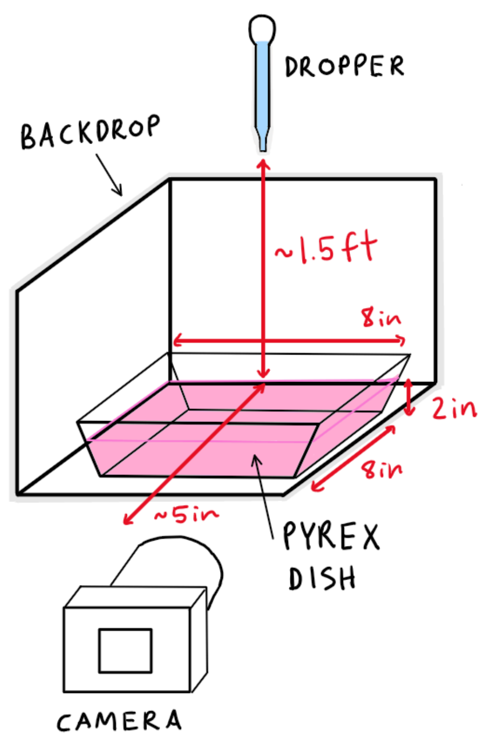


Fig.1. Set-Up Schematic

Several aspects can be examined from the image of this flow. The first of which is the two noticeable droplets rising into the air. These are droplets rebounding after hitting the water's surface, and are moving upward in the image. Droplets are able to rebound from liquid or solid surfaces when a thin stable vapor layer is able to form beneath the droplet as it hits the surface. This layer prevents the droplet and surface fluid below from combining and allows the droplet to rebound back into the air[4]. The second notable aspect of this image is the column of liquid that follows the droplet from the water's surface. This column is a form of a Worthington jet, where the collapse of the air cavity from the droplet's initial hit results in the rest of the water rushing to fill the cavity, which is then brought upwards by the rising droplet. This is also a result of surface tension[3].

The aspects discussed above can be applied to many liquids; however, some aspects of my image in particular may alter some of these phenomena. Because my image is of a 1:1 cornstarch and water slurry dropping onto a water surface, some differences are likely present. The primary difference is likely due to the different behavior of the non-Newtonian cornstarch slurry. Although the slurry is not fully "oobleck", a 2:1 cornstarch-water mixture, it still has non-Newtonian properties and becomes shear-thickening[2]. These fluids behave differently under shear stress, and in the case of oobleck, it will behave as a solid. This fact likely accounts for the more distinct Worthington jet, which appears to have a thicker base and a more distinct rise. The jet still likely consists of almost all water from the surface; however, it does follow the non-Newtonian droplet using surface tension as it rebounds.

The Reynolds number for this Worthington jet flow can be calculated using

$$Re = \frac{U\ L}{\nu}$$

where U is the fluid's velocity, L is the length dimension of the fluid, and ν is the fluid's kinematic viscosity. Here, U can be estimated to equal 2 in/s, L to equal 1 in, and ν to equal 0.000010789 ft^2/s. These calculations are fully shown in the appendix and give a Reynold's number of 1282. This is below 2300, classifying it as laminar flow, which makes sense based on the flow's smooth and non-turbulent form.

To visualize this flow, watercolor paint dye was used for both the slurry and the surface. The surface of the water was pink from previous experiments and the slurry was dyed blue. The slurry was a 1:1 mixture of water to "Argo" brand cornstarch, but was not thick enough to be considered "oobleck". Overhead ceiling lighting was used.

This fluid motion was captured on my Nikon D80 camera with an ISO of 1600, a shutter speed of 1/250, and an aperture of f/5.6. This was taken with an 18-135mm lens with a focal length of 58.0mm. The field of view is approximately 6in x 4.5in. The flow phenomena was approximately 5 inches from the camera lens. The original image had pixel dimensions of 3900x2613 and the post-processed image had pixel dimensions of 1264x1263. During post-processing I altered the color balance rgb, sigmoid, local contrast, sharpness, crop, and noise. My primary intent with post-processing was to reduce the noise in the original image and increase the color contrast. The original image can be seen below.

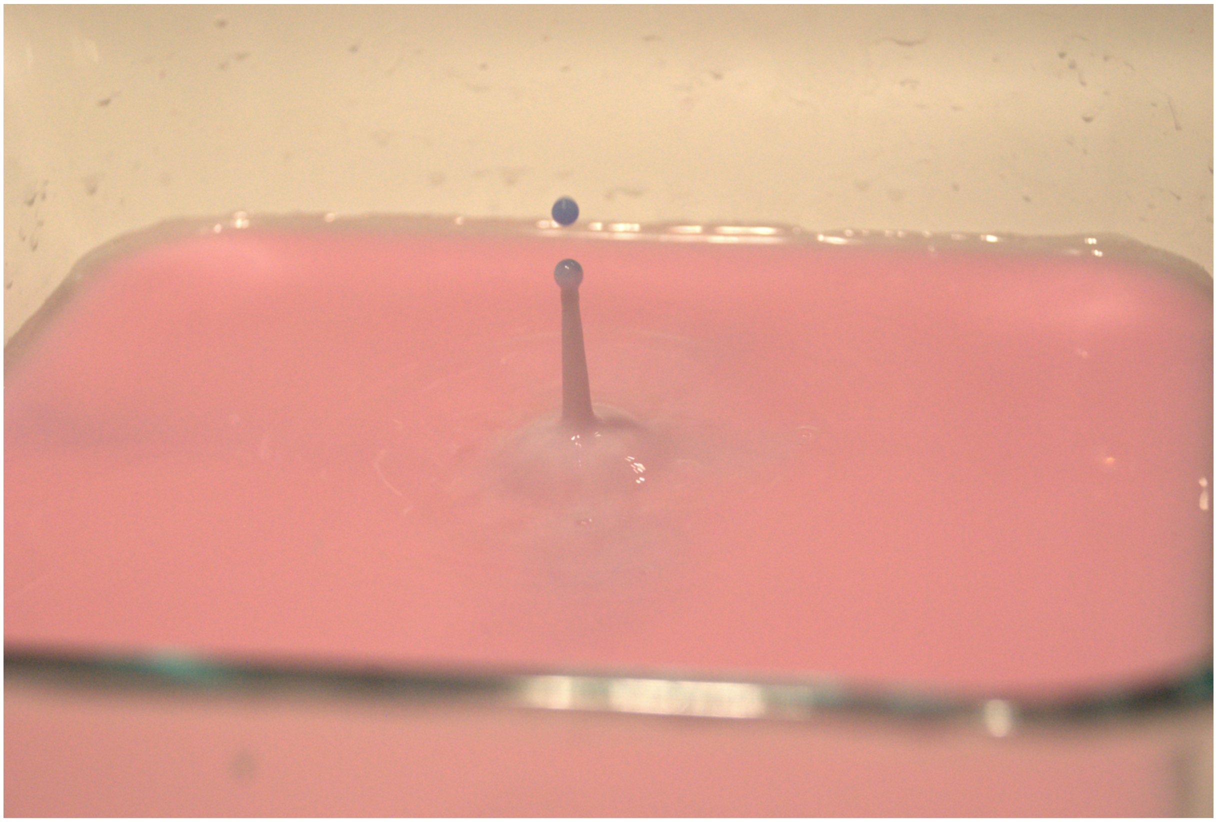


Fig. 3. Original Image for Team Third

Overall, this image reveals the effect of a droplet bouncing off from a surface and the Worthington jet that can be formed. It also shows how a non-Newtonian droplet can affect the behavior of the droplet and jet. The Reynolds Number was evaluated to be 1282, classifying the Worthington jet as laminar flow. Artistically, I like the colors in this image, along with the textures and soft curves present. I feel that I have fulfilled my intent with this image, especially by learning more about how to capture faster moving objects. However, I would like to improve on capturing fast moving objects with better resolution, as I feel I could have better achieved that. After photographing this image, I am curious to know how viscosity affects the droplet's response, and how a 2:1 ratio of oobleck would respond. If I were to develop this idea further I would experiment with different concentrations of cornstarch and water slurries and experiment more with droplets from different heights.

REFERENCES:

[1]Editor Engineeringtoolbox. (2004, January 25). *Water - Dynamic and Kinematic Viscosity at Various Temperatures and Pressures*. Engineeringtoolbox.com. http://engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html

[2]*The mystery of oobleck: insights on shear thickening - Department of Physics*. (2016, May 6). Department of Physics. https://physics.georgetown.edu/news-story/the-mystery-of-oobleck-insights-on-shear-thickening/

[3]Yamamoto, K., Motosuke, M., & Ogata, S. (2018). Initiation of the Worthington jet on the droplet impact. *Applied Physics Letters*, *112*(9). https://doi.org/10.1063/1.5020085

[4]Yu, X., Zhang, Y., Hu, R., & Luo, X. (2021). Water droplet bouncing dynamics. *Nano Energy*, *81*, 105647. https://doi.org/10.1016/j.nanoen.2020.105647

APPENDIX:

A. Calulations
   a. General Properties, Assumptions, and Notes:

Property (With reference #)	Name	Value
U	Estimated Velocity of jet	$1in/(0.5s) = 0.167\ ft/s$
L	Characteristic Length of jet	$1in = 0.083ft$
ν_{20C}	Kinematic Viscosity of water at room temperature[1]	$1.0789ft^2/s \times 10^{-5}$

Assumptions:
- The experiment was conducted at room temperature
- The Worthington jet can be assumed to have the kinematic viscosity of water

Equation 1: $Re = \frac{U\ L}{\nu}$

   b. Reynold's Number Calculations for jet:

Equation 2:

$$Re = \frac{U\ L}{\nu}$$

$$Re = \frac{(0.167ft/s)(0.083ft)}{1.0789e{-}5ft^2/s}$$

$$Re = 1282 \rightarrow laminar\ flow$$