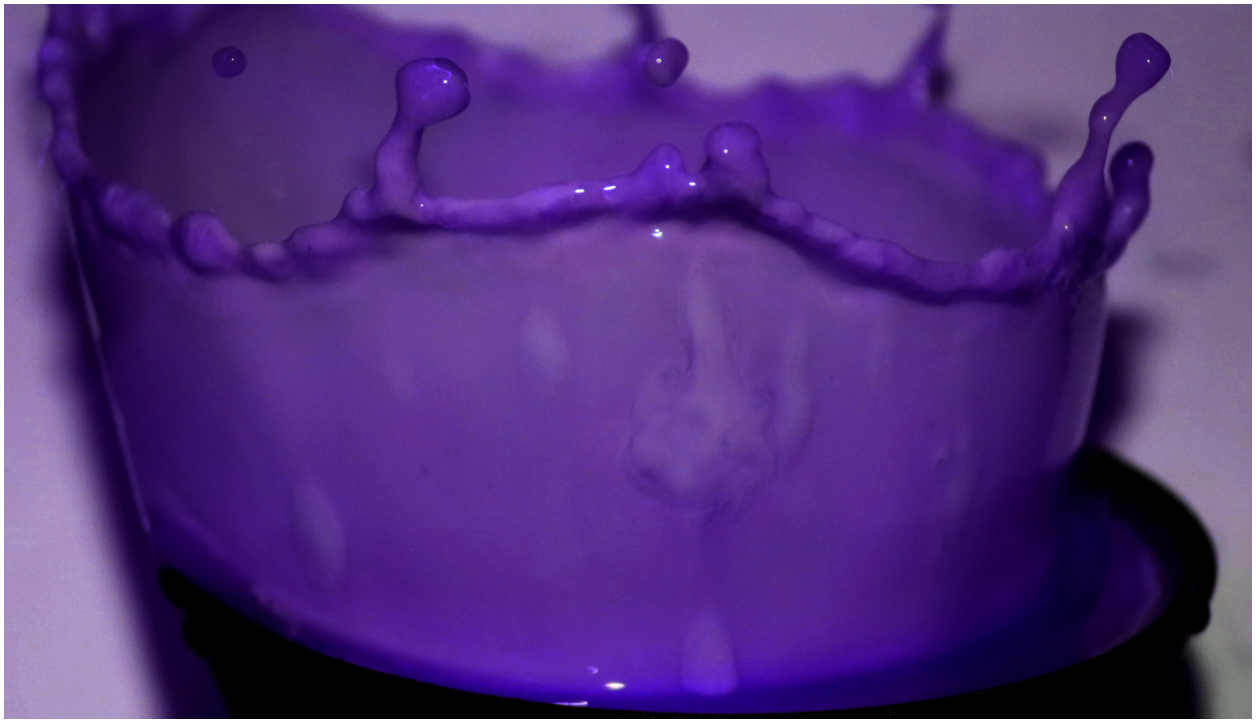
Image Report 4
Flow Visualization | CINE 4200

Trevor Peterson | 12/13/21



Introduction:

For the fourth and final image of the class, a highly viscous fluid was produced which a rock was dropped into. By allowing the rock to fall from a high enough height, a crown instability in the resulting splash of the rock was captured. The intent of the image was to capture a fluid of unusual characteristics and high viscous properties. This was accomplished by utilizing a mixture of cornstarch and water to a specific ratio and then introducing a specific impact force to the surface of the fluid. The image was then edited with various techniques available in standard photo editing software.

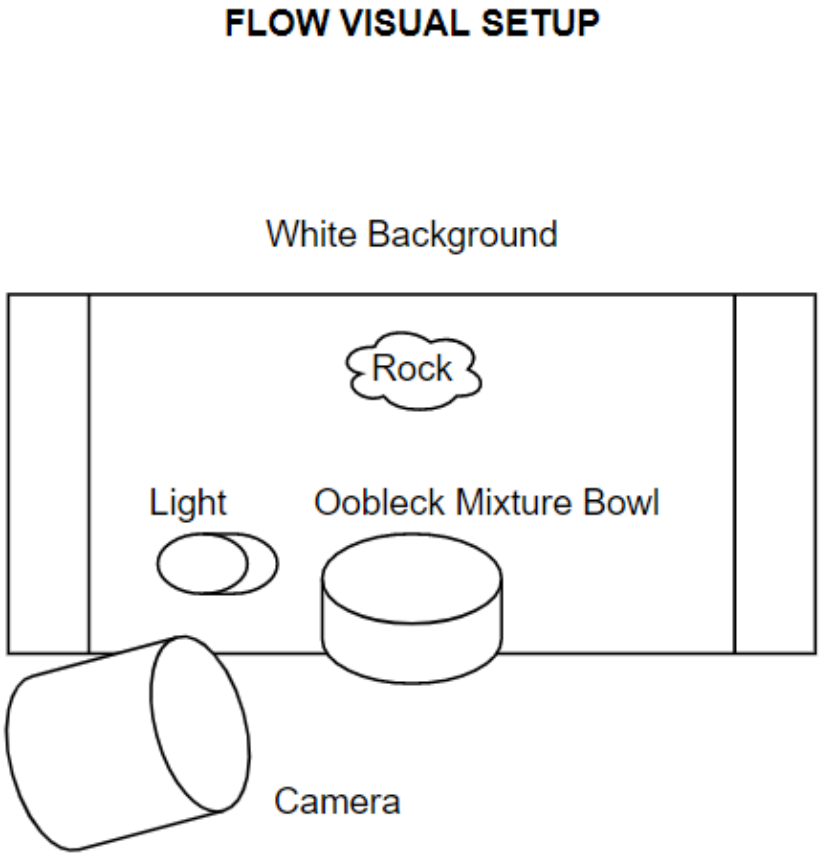


Figure 1. The set up for taking the image, with the rock to be dropped directly onto the fluid.

Analysis:

The flow was captured as shown in the image above, where the flow itself was the result of dropping the rock onto the non-Newtonian fluid. The crown is approximately 1.5 inches in height and rises in a hyperbolic profile from the fluid, with specific droplets at distinct heights around the rim of the crown.

The bowl was mixed with a mixture of both water at room temperature of approximately 25°C and cornstarch. The ratio of cornstarch to water was approximately 1.5 parts to 1 part. The fluid at this stage was viscous enough to resist quick stabbing with a spoon. A white background was chosen to highlight the golden color of the fluid that was created after adding a tsp of coffee.

The instability levels of the crown are related to the Weber number for the drop or impact object.[1] The Weber number can be calculated with the following formula:

$$We_{rock} = \rho v^{*2} d/\sigma$$

where v^* is given with the following equation:

$$v^* = \sqrt{2gH}$$

With the values of g = 9.81m/s^2 and H = 0.203m, v^* = 2.12m/s. Furthermore, the values for ρ_{rock} = 1600kg/m^3,[2] d = 0.04m, and σ being the surface tension of the non-Newtonian fluid, which varies with the force of the impact object.

For water, surface tension is 72*10^{-3} N/m.[3] Using this as a lower bound for the non-Newtonian fluid, the Weber number for the rock dropping onto the non-Newtonian fluid is at least 4016. Since regular crowns are typical of Weber numbers around 400, this setup suggests that the crown instability will be fairly unstable. This can be seen in the photo, as the spikes of the crown are inconsistent in distance and form.

Figure 2. Full unedited image of the non-Newtonian fluid and rock impact.

Another interesting characteristic of the flow that was observed is more noticeable in the final edited image with color adjustments and higher contrasts. This is the instability of the coffee added to the non-Newtonian fluid showing the path of the fluid as it moves upward to form the crown. Seen below, the difference in colors in the middle of the face highlights the larger velocity of the fluid moving upward in portions of the crown instability that are creating spikes.

Technique:

The setup shown in figure 1 above shows a background of solid white paper, with a bowl of non-Newtonian fluid in front of it. The lighting from an iPhone XR flashlight was pointed from the left to the right towards the bowl of fluid, and the rock was held approximately 8 inches above the bowl to be dropped in. The rock was approximately 1in in diameter. The camera itself was held at a distance of approximately 10 inches from the bowl with its focus set at the bowl's edge length.

For this project, a Canon Rebel SL2 was borrowed and used to capture the image. The camera was on manual focus for the image, as it was important for me to capture the front edge of the crown instability. The ISO was set relatively high at 3200 due to the flash being on, and f/5.6 was utilized to increase the depth of field as the entire crown is not in a 2D plane relative to the lens of the camera. With a 1/60 shutter speed, there is little blur, allowing for a crisper photo. The photo was originally 6000x4000 pixels before editing.

For this photo, I wanted to experiment more heavily with the editing than images I had done in the past. With goals to increase the contrast in the image to make the shape of the crown clear, as well as highlight the variation in the face of the crown in the middle, I prioritized adjusting contrast and increasing shadows on the image slightly. Furthermore, I also adjusted the base curves to bring out more of a purple and blue hue that helped increase the contrast in the crown created by the small amount of coffee in it.

Opinion:

The goal of this image was to capture crown instability and observe the behavior that arose with a non-Newtonian fluid with this setup. Furthermore, I wanted to expand on my DSLR knowledge and editing skills in the post-processing portion. This fluid setup not only allowed me to observe that the viscosity of the fluid plays a factor in the crown instability formation, but also that with adjustments to the coloring and base curves of the photo, features can be highlighted that were not apparent in the original image.

In the future, I would like to try this set up with an impact object more similar to a drop of water, and with a much less viscous fluid to see how stable of a crown I could recreate.

Sources:

1. *Crown-Forming Instability Phenomena in the ... - Ualberta.ca*. http://www.math.ualberta.ca/~rkrechet/files/publications/jcis2009.pdf.
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3. "Surface Tension." *Surface Tension - an Overview | ScienceDirect Topics*, https://www.sciencedirect.com/topics/earth-and-planetary-sciences/surface-tension#:~:text=Because%20of%20the%20relatively%20high%20attraction%20of%20water%20molecules%20to,F)%20than%20most%20other%20liquids.
4. Kundu, P. K., Cohen, I. M. "Fluid Dynamics", 4th Edition, Academic Press, 2008