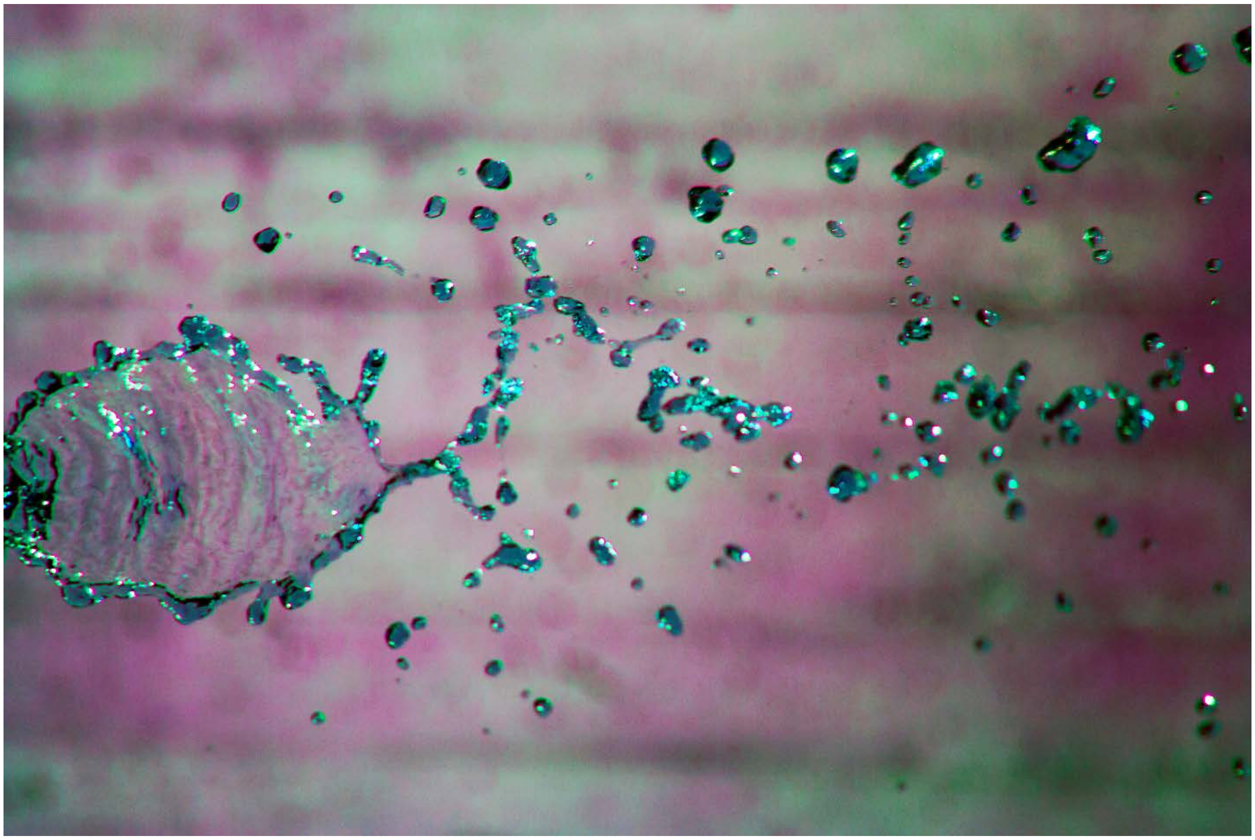
Third Team Project:

Fishbone Instability



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Purpose

For the third group image we wanted to produce a fluid phenomenon that was beautiful yet scientific. One of our group members, Ryan mentioned having seen an amazing phenomena called the "fishbone effect." A little research into this idea lead us to knowing that it is an instability that can occur when two streams of fluid collide and form a shape reminiscent of a fishbone so we aimed at mimicking this effect. So we went into experimenting with colliding two jet streams at different velocities and angles until a collection of photographs were created to pick from

Procedure/ Visualization Technique

To recreate the fishbone instability, two different bottles, a cola bottle and a water bottle had a 6 mm hole drilled into the caps and then a five inch piece of a drinking straw inserted into these holes. The use of two different bottles was not to create a specific effect, but because that was what was available to use from the recycling bin. A large bucket was filled with water. Red and blue food dye were added to the water to make the color light purple. The caps of each bottle were taken off and the bottles were then dunked into the water to fill them up. Both bottles were then aimed at each other at a 45 degree angle from horizontal and squeezed with maximum force in a plane perpendicular to the lens of the camera. The experiment took place outside in bright sunlight. The flow apparatus described can be seen to the right in Figure 1.

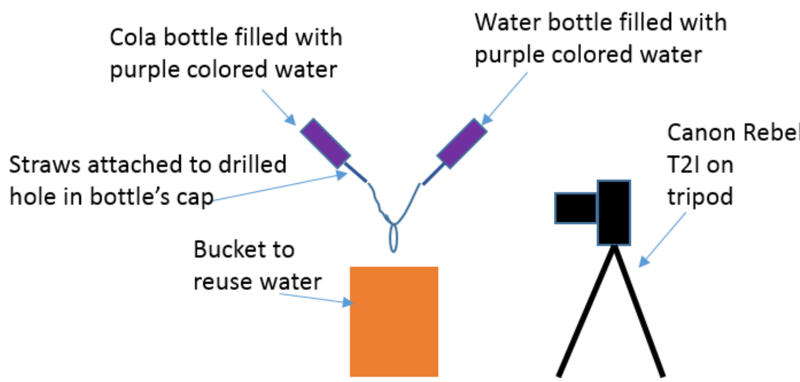

Figure 1: Schematic of flow visualization apparatus

Physics Involved

The wave appearance in the picture is caused by a Plateau-Rayleigh Instability which is a property of liquids that causes them to aim at minimizing their surface area by forming into a stream of droplets. This is an instability that occurs when water drops from the tap of a sink or when a male urinates.[i] Defining more of the specifics into the stability of the two colliding jet streams relies largely on the two dimensionless parameters, the Reynolds number and the Weber number.[ii] These two parameters rely heavily on the diameter of the droplet and the velocity of the fluid. When velocities are low, a "clear fluid chain occurs."[iii] As the velocities increase, the behavior changes drastically. The assumption is made that the streams are flowing at 2 m/s and that the water is at 20 degrees Celsius.

$$v_{stream} = 5\frac{m}{s}, \rho_{water} = 1000\frac{kg}{m^3}, \mu_{water} = 1 * 10^{-3}\frac{N * S}{m^2}, \sigma_{water} = .0728\frac{N}{m}$$ [iv]

$$D, l = diameter\ of\ stream\ through\ drinking\ straw = 6mm = .006m$$ [v]

$$Re = \frac{\rho_{water} v_{stream} D_H}{\mu_{water}} = \frac{1000\frac{kg}{m^3} * 2\frac{m}{s} * .006m}{1 * 10^{-3}\frac{N * S}{m^2}} = 1.2 * 10^4$$

$$We = \frac{\rho_{water} {v_{stream}}^2 l}{\sigma_{water}} = \frac{1000\frac{kg}{m^3} * \left(2\frac{m}{s}\right)^2 * .006m}{.0728\frac{N}{m}} \cong 300$$

In the research article, “Dynamics and Stability of Impinging Jets,” extensive research was done on this “fishbone” phenomena, and with the Reynolds and Weber numbers calculated, we can put a point on their plot of appearance vs. simulation results in Figure 2. From appearance alone, the picture captured is somewhere in between cases (d) and (e) that they created (shown in Figure 3 below) and the plot confirms this. A star is added to the plot in the location of the Reynolds and Weber numbers of the fluid phenomena captured in the picture. The star is extremely close to the “unstable rim” and “impact wave” cases which is also resembling of cases (d) and (e).

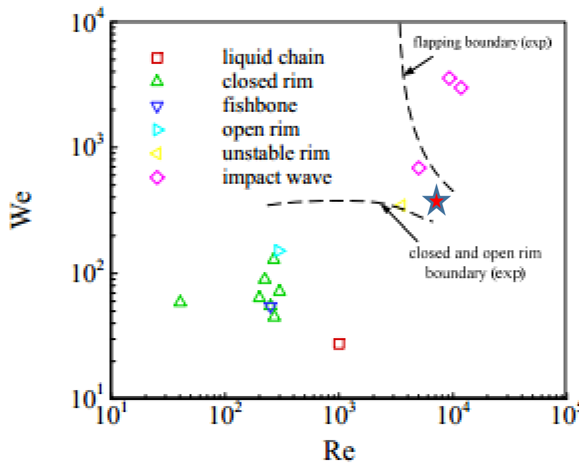

Figure 2:Plot of different flow appearances against Reynolds number and Weber number from: http://www.ilass.org/recent/conferencepapers/48.pdf

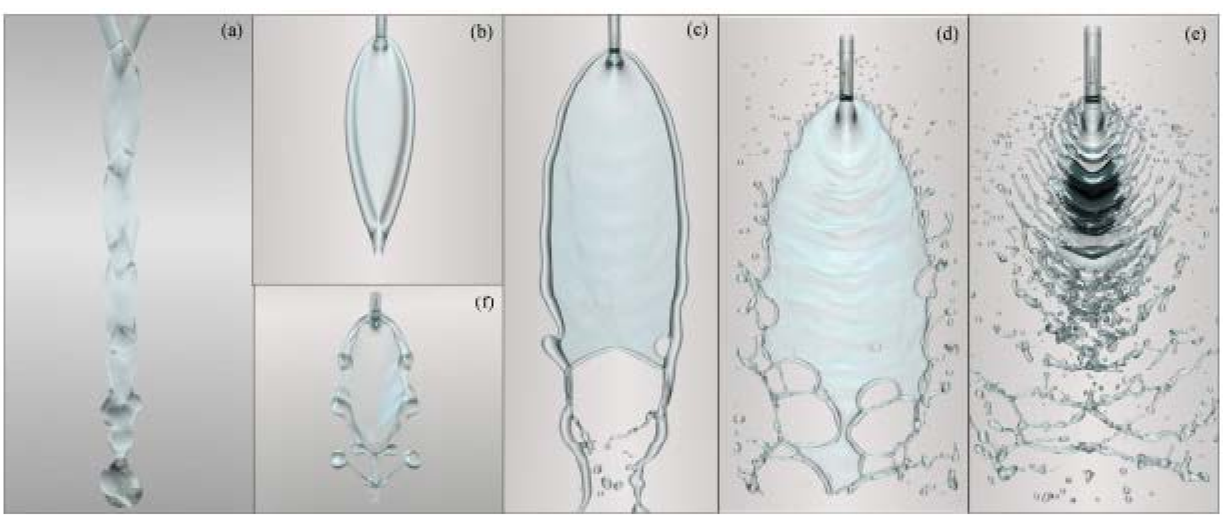

Figure 3: Results of increase in velocity of two colliding streams. from: http://www.ilass.org/recent/conferencepapers/48.pdf

Photographic Technique

This photograph was taken with a Canon Rebel T2I with the sunlight to illuminate the water being sprayed out of the bottles. The distance from the water streams to the lens was about a foot and a half, and the aperture was at 4.5. The shutter speed was at 1/3200, the focal length at 50 mm, and the ISO at 800. The original image's size is 3456 x 5184 pixels with the edited image being turned into a landscape style photograph.

For post-processing, Photoshop was used. I decreased the brightness of the photograph, altered the hue to more of a blue theme and increased the saturation. I also slightly decreased the exposure. The image was rotated -90 degrees and then flipped horizontally.

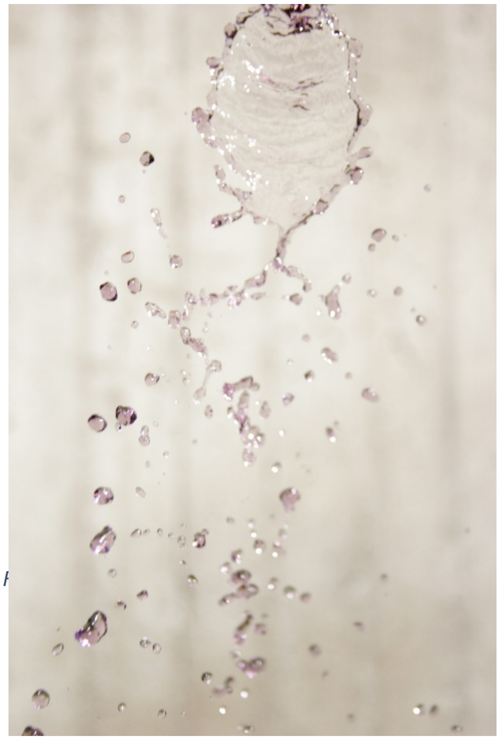

Figure 4:Original Image

Conclusion

I believe this image captured a fishbone stability beautifully. It was incredibly hard to create this effect with as unpredictable of a stream as we were dealing with and I am glad it was accomplished. It was also very interesting that the results matched up with those in research studies. To improve the experiment, I would create a more stable setup and alter the velocities to watch the instabilities grow.

Special thanks to my group: Ryan Coyle, Philip Latiff, and Michael Mccormack

Bibliography

[i] http://en.wikipedia.org/wiki/Plateau%E2%80%93Rayleigh_instability
[ii] http://www.ilass.org/recent/conferencepapers/48.pdf
[iii] http://fuckyeahfluiddynamics.tumblr.com/post/43648531738/when-two-liquid-jets-collide-they-can-form-an
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