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Team Third Report

The team third assignment prompts team to complete one final experiment to capture a beautiful and artistic example of fluid flow. With the assistance of multiple team members, it is possible once again to develop a complicated experiment and capture the image with ease. On the other hand, sometimes there is beauty in simplicity. My group decided with our final project that we would focus on the artistic nature of fluid flows. The first two assignments we captured some great fluid phenomena, but we lacked the setup to produce a beautiful image, even with post processing. We decided to go back to the basics and spend more time setting up the experiment with lighting, background, and a very nice camera instead of creating a complicated experiment related to fluids. Ironically, we chose to look at the spherical and chaotic nature of vegetable oil bubbles introduced to a water cup at a high velocity. All of our experiments were related to bubbles. This is not necessarily due to a lack of originality; our group was just interested in bubble physics which is surprisingly an extremely complicated subject.

Within the image, it is important to note the spherical and chaotic nature of the bubbles. The physics behind the image is fascinating, as the two fluids are fighting against each other due to their physical properties. The surface tension of the water is pushing against the vegetable oil to break apart and shape the liquid that simply entered as a stream of liquid. As mentioned in previous papers, bubble physics is difficult to quantify, and thus quite a bit of discussion on the phenomena will be revealed rather than an attempt to quantify values.

While the vegetable oil was introduced to the water as a stream of fluid, the reader will notice that the stream breaks into smaller bubbles due to the Rayleigh-Plateau Instability. This effect is generally seen with stream of liquid under the effect of gravity, such as a small stream of water falling from the faucet and breaking apart near the end. The idea behind the instability is that under gravity, there will be perturbations in the radius of the jet stream that eventually allow surface tension to split the stream [2]. In the case of my experiment, these forces exist as viscous effects. The viscosity of water and vegetable varies enough to where the stream is disturbed and broken apart – forming spherical droplets due to surface tension. In addition, the impact speed of the vegetable oil with the surface of water plays an effect as a body force (or outside force) disturbing the geometry [2].

Below, I will explain more of why the stream breaks apart. Assuming the vegetable oil stream is a cylinder with radius R, it begins to oscillate with a new radius R(x). It forms two points in the perturbation: one concave and one convex as the surface tension begins to break the stream apart[1]. The radius of curvature of the oscillating area radius is defined by

$$k_x = -\frac{\frac{d^2R}{dx^2}}{(1+(\left(\frac{dR}{dx}\right)^2)^{\frac{3}{2}}} \sim \frac{1}{R}\ [1]$$

This value is easy to approximate with our experiment, as the exit diameter of the vape bottle was no more than 3 mm. In addition, the pressure at the concave and convex points can be determined through the following, [1]

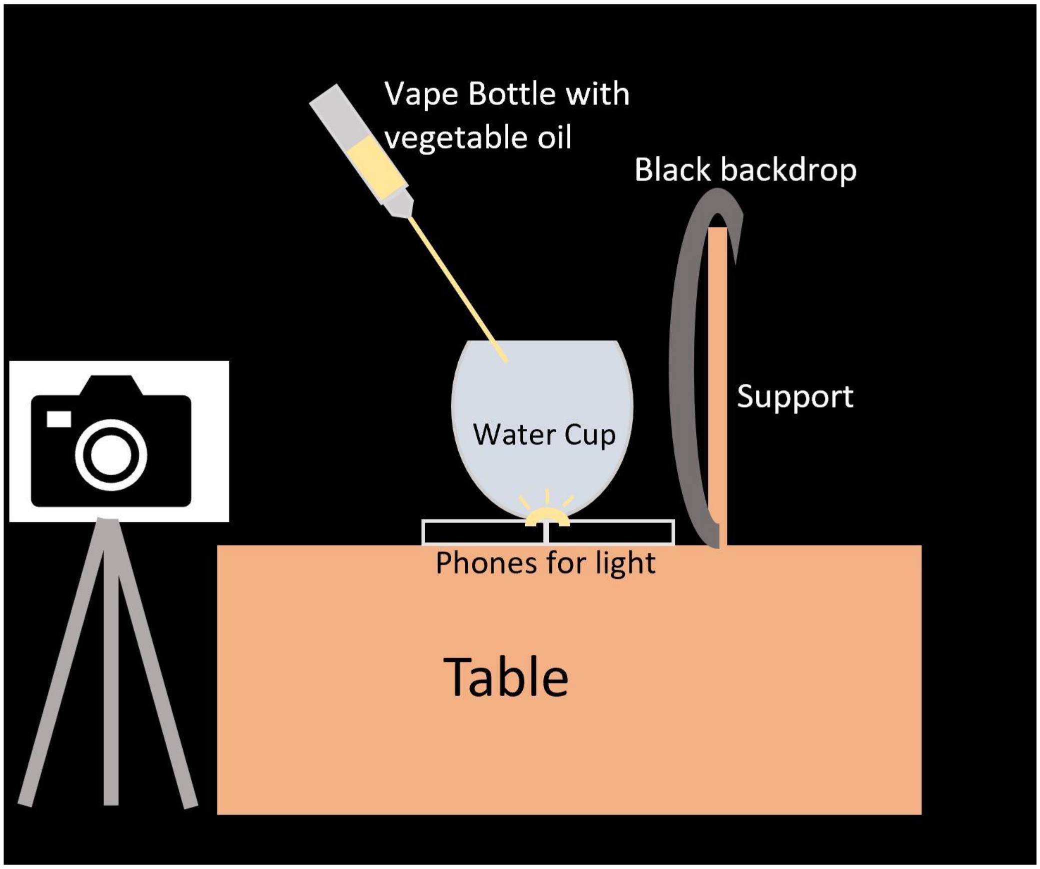
$$p(Convex) = p_{atm} + \frac{\gamma}{R(Convex)}, p(Concave) = p_{atm} + \frac{\gamma}{R(Concave)}$$

$$p(Convex) = 14.7\,psi + \frac{0.91\frac{g}{cm^3}}{3\,mm} = 14.7\,psi + \frac{\frac{.002\,lb}{0.061\,in^3}}{0.118\,in} = 14.98\,psi$$

$$p(Concave) = 14.7\,psi + \frac{0.91\frac{g}{cm^3}}{2\,mm} = 14.7\,psi + \frac{\frac{.002\,lb}{0.061\,in^3}}{0.0787\,in} = 15.1\,psi$$

where gamma is the specific gravity of the liquid. As shown above, the pressure is larger with the concave point. This pressure differential accelerates the fluid from high pressure regions to low pressure regions and breaks the steady state time-invariance [1]. The breakup of the fluids is a nonlinear process that I will not cover for the sake of complexity.

The set up for the experiment was not as difficult as originally intended and can be shown in the diagram below. The water cup was sitting on two iPhones with flashlights to illuminate the experiment from below. To ensure the background was free of distractions, the team used a black backdrop provided by Professor Hertzberg draped over some structural support (in this case, in the form of soap bottles). The vegetable oil was loaded in an empty vape juice bottle and was easily shot out into the water cup. The bottle was held approximately 8 inches diagonally with respect to the edge of the water. The decision not to release the vegetable oil directly above the water cup stems from the group's effort to create an interesting, artistic image. The camera rested near the edge of the table, approximately 5 inches from the water cup and focused accordingly. The setup for the experiment was completed with the effort of my team members: Meg Ivy, Dawood Ahmad, Faisal Alismail, and Sam Brown.



The camera used to capture the images was a SONY ILCE-7RM2. Its quality was exactly what we needed to capture an artistic image. The aperture was set at f/4.0, shutter speed was 1/4000 seconds, and an ISO of 102400. The original image size was 7952 x 4472 pixels, as the image was captured with a wide-angle lens. The final image was cropped to 5600 x 4368 pixels. The resolution was 300 pixels per inch. The original image is shown below

Some post processing was completed to add to the artistic portion of the image. First, my intent after seeing my picture was to reduce a portion of the boundary to appear as if the bubbles were floating in space. I then decided to keep a portion of the boundary to address the realism of the photo and describe the beauty in something realistic. First, using the NIKON software before opening Photoshop, I adjusted the temperature of the photo. The following settings were adjusted while the other settings were maintained at 0.

Feature	**Value**
Temperature	7850
Tint	+60
Contrast	+21
Shadows	-72
Whites	-1
Blacks	-11
Texture	-44
Clarity	+27
Dehaze	-3
Vibrance	-3
Saturation	-2

After exiting the NIKON settings, I entered photoshop to make adjustments to the sharpness, crop the image, and blur the bottom of the image to remove the light spots from the flashlights. First, I adjust the image more using curves. The final settings using curves was an input of 231 and output of 220 at the second tick mark in curves. This helped to decrease the visibility of the edges on the cup. Next, I used the blur tool to smudge the bottom of the glass and create more of a light dispersion. I think it is the most unrealistic part of my photo but also enjoy the texture, so I decided to keep it. Finally, I added some of the black from the background to the boundary using the clone stamp tool. This removed any areas of the figure that were distracting.

Overall, I believe the intent of the art was realized and felt like I had a better idea of how to capture a visually stunning picture. While the flow above is simple, I enjoyed working on the post processing of the image and discovering new tools to incorporate into future pictures. If I conducted this experiment again, I would use more light. The blur in the image was surprisingly due to the lack of light coupled with the ISO rather than a low shutter speed. Based on the response from the class, it seems like the general consensus was the blur was interesting and realistic, however capturing this experiment with a crystal-clear picture would be amazing. Comments on the effect of the image, post-processing, and other suggestions related to the image are always greatly appreciated.

References:

[1] Gallaire, F., Bran, P.T., (2017). Fluid Dynamic Instabilities: theories and application to pattern forming in complex media. Philosophical Transactions. A 375: 20160155. Retrieved from: https://royalsocietypublishing.org/doi/pdf/10.1098/rsta.2016.0155

[2] Hedge, Milind (2013, Sep 1). Fluid Dynamics and The Plateau-Rayleigh Instability. University of California Berkeley. Retrieved from: https://math.berkeley.edu/~mhegde/pdfs/Project%20Report%20-%20Fluid%20Mechanics%20and%20the%20Plateau-Rayleigh%20Instability.pdf