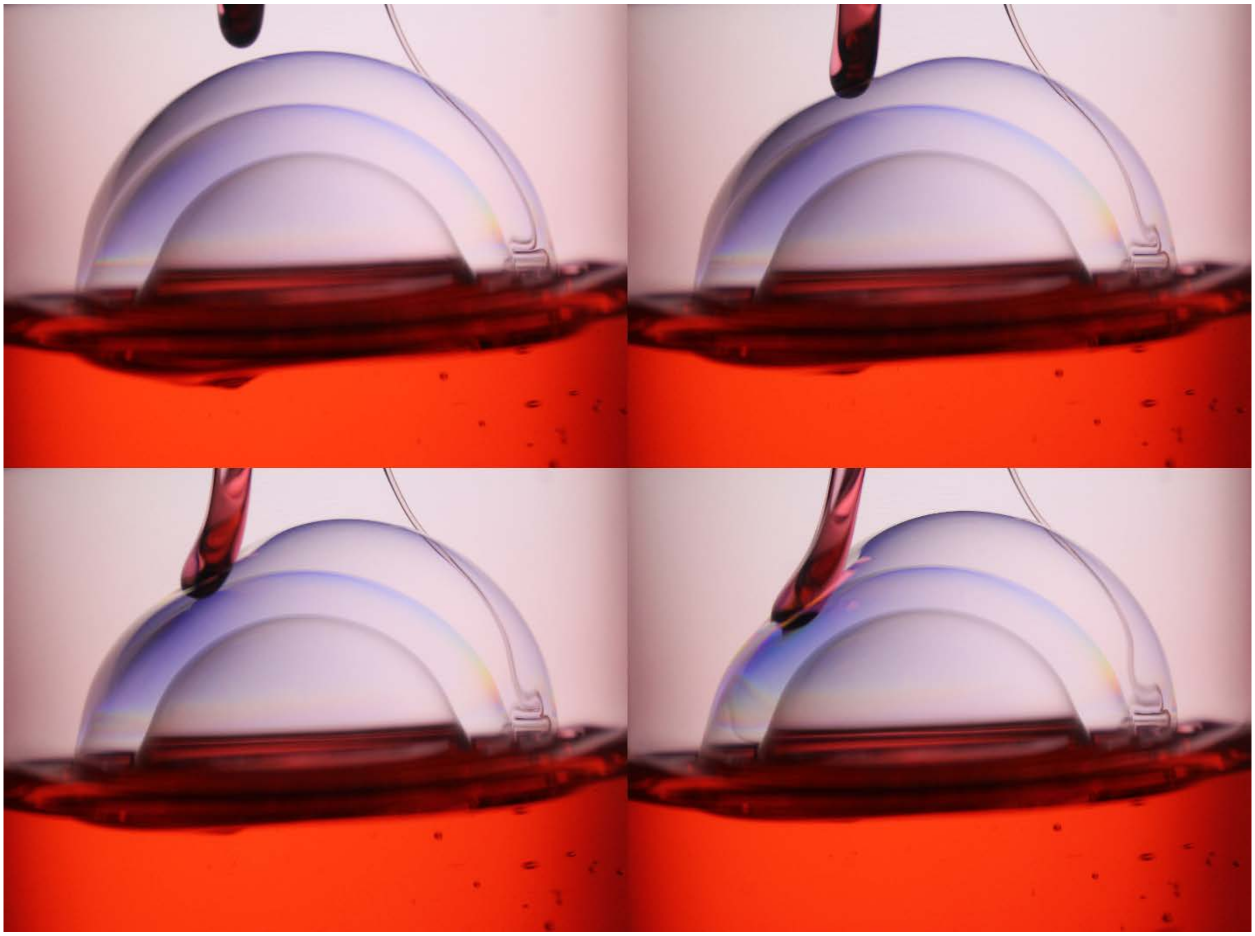
Team Project 2



MCEN 5151 – Flow Visualization
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Introduction:

The purpose of the team image is to capture a beautiful flow image that is a little more complex than the Get Wet image. Looking for something to take a picture of, I went to professor Hertzberg's office to see what she might recommend. With tons of desktop flow toys to pick from, I decided to use the goo tube just because the color was so bright. I did not even a little bit expect to get the amazing fluid moment out of it that I did. Sometimes even the simplest things can really surprise you!

Physics:

A simple schematic showing the flow set up is shown below in figure 1. The goo tube was simply flipped upside down and placed on a laptop keyboard with the laptop shining a clean, white light. As the goo drained, large bubbles formed on the top layer. At the same time, some fluid stuck to the top of the tube would occasionally drip down into the top layer of fluid. The camera was about 4 inches away and the final field of view is about 2.5 inches in each image.

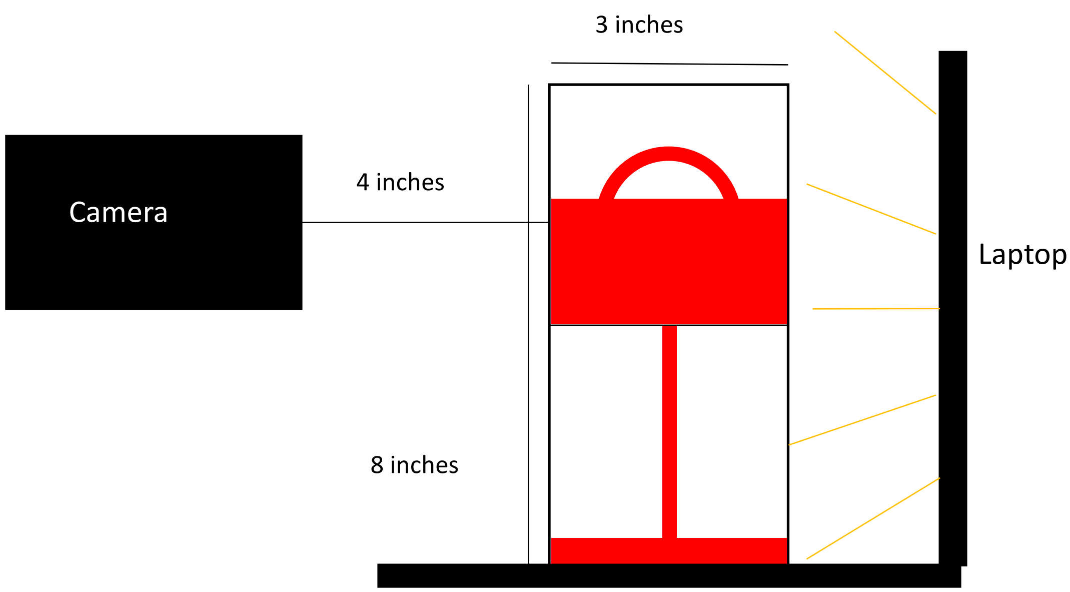

Figure 1 - Schematic of the Experiment

Because this is more of a real world scenario than an experiment to duplicate a certain phenomenon, there are a lot of different fluid phenomenon happening in this image. I will describe the physics of one of my favorite elements of this picture, the coiling instability exhibited by the secondary stream behind the bubbles. However, if you are interested in more, I recommend finding other pictures and the associated reports on other phenomenon such as thin-film interference, and bubble stability from surface tension.

Liquid rope coiling is a very common, but quite complex fluid phenomenon. It basically occurs due to buckling. Much like when one squeezes a straw, it buckles outwards, when these ropes have a compressive stress from the bottom surface, they buckle outwards[1]. However, it is very complex because the ropes deform simultaneously due to bending, twisting, and stretching[2]. There are three distinct coiling regimes depending on fluid properties, fall height, and flow rate[1]. They are the viscous, gravitational, and inertial coiling regimes, and they occur when their namesake forces outweigh the other forces (i.e. for viscous coiling, viscous forces outweigh gravitational and inertial forces). Typically viscous coiling occurs when something begins coiling very shortly after it falls (toothpaste on a toothbrush), gravitational coiling occurs when a fluid falls a moderate distance (what we have in this picture), and inertial coiling occurs when fluids fall from a great height[1].

The main difference between these three regimes is the coiling frequency. The coiling frequency for the gravitational regime is given below[2].

$$\Omega = \left(\frac{Q^4}{\nu a^{10}}\right)^{1/3}$$

Where Q is the volumetric flow rate, v is the kinematic viscosity, and a is the radius of the rope. Surprisingly, surface tension plays a very minor role, and doesn't factor into the coiling speed in any of the regimes. At this point, it would be great to be able to solve for coiling speed! However, because the goo tube is simply a desktop toy, there is very little information about it. While the flow rate and rope radius may be estimated with relative accuracy, there is no way to know what sort of fluid is in the tube. Therefore, I would never be able to find a reasonable approximation for kinematic viscosity.

Photo Setup:

The setup for this photo was very simple. The goo tube was just flipped upside down and placed on a laptop keyboard. The laptop was set to just shine a white light to provide clean, good looking lighting that would make the gorgeous red fluid really pop. A schematic of the set up was shown in figure 1.

As for the actual experiment and photography, the camera was held directly across from the laptop screen, about 4 inches from the tube. The tube is about three inches in diameter, and the outer most bubble took up most of that space. The flow was actually very easy to photograph because it moves so slowly since the fluid is so viscous. The jet coming down and impinging on the bubbles dripped so slowly that I had plenty of time to get set up and focused before it got close the bubble. When it did get close, I just took photos as fast as I could and got lucky to see such deformation in the bubble.

Photo Technique:

The photos were taken with a Canon EOS Rebel T2i D-SLR camera. The original photos can be seen below in figure 2.

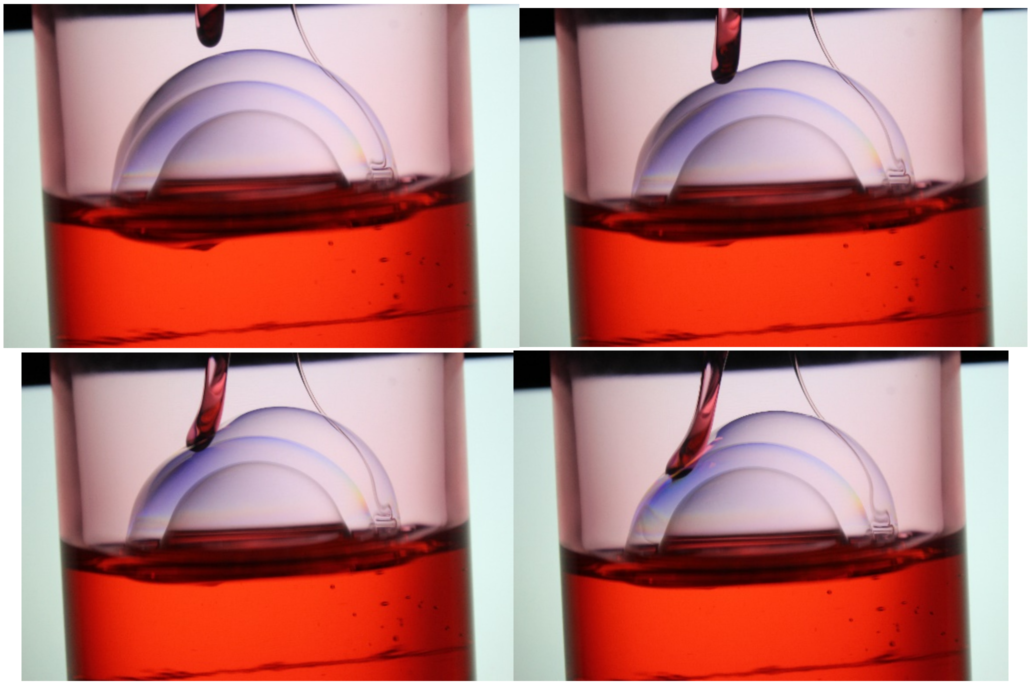

Figure 2 - Unedited photos

The field of view in this image is about 4 in each direction with pixel dimensions of 5184x3456. The photo was taken with the camera about 4 inches away. The lens used was just the stock lens that came with the camera. It has a focal length of 18-55 mm and a focus distance of 0.8 ft to infinity. For these images, a shutter speed of 1/60 s, an aperture f-stop of f/4.6, and an ISO setting of 500 were used. These values are the ones the camera picked automatically. I know it's possible to get better pictures by tweaking those values, but it seems that when I try to do it the image just gets worse than the automatic settings. Therefore, I decided to just let them be.

After the image was taken, there was some minor post processing done in Gimp. The image was cropped to get rid of the distortion caused by the tube and the black bar at the top where the laptop light ends. The cropped images all had the same pixel dimensions of 3740x2778 and the field of view was reduced to about a 2.5 inch square for each image. After cropping, I simply place the four images in the configuration shown. The pictures turned out surprisingly well, and I didn't see any need to mess with color, contrast, or brightness of the photos.

Conclusion:

I feel this image does a great job of capturing the amazingness of this goo tube. The pictures came out great and showed several good fluid phenomena. The only thing I don't really like about the image is that every picture is a little crooked. This seems to be a common occurrence with photos of mine and is something I should work on correcting in future work. There isn't much that can be done in future work with the goo tube, however, there is a lot I could do to further my study of the rope coiling phenomenon. To start, I could use a known substance so the fluid properties could be used in calculations. Beyond that, I could try to get all three different coiling regimes. This is one of my favorite fluid phenomenon, so I may be doing exactly that in the final image of this semester.

References

1. Maleki, M., M. Habibi, R. Golestanian, N. Ribe, and Daniel Bonn. "Liquid Rope Coiling on a Solid Surface." *Physical Review Letters* 93.21 (2004): n. pag. *APS Physics*. Web. 11 Apr. 2014.
2. Ribe, N. M. "Coiling of Viscous Jets." *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 460.2051 (2004): 3223-239. *Royal Society Publishing*. Web. 11 Apr. 2014.