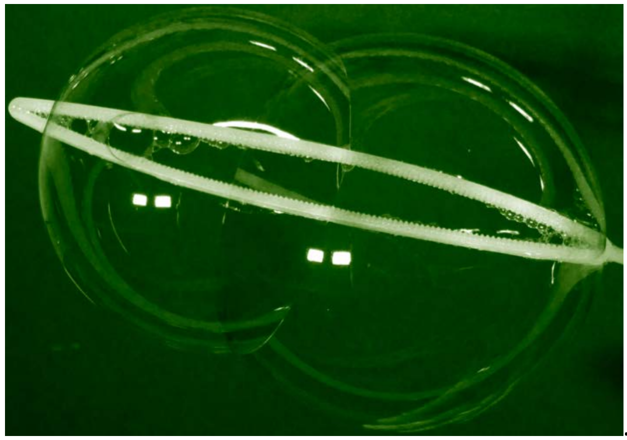
Sreyas Krishnan
5/3/2012
Flow Visualization
Team Photo #3



For this image, I captured two bubbles sitting on a soap-soaked bubble-wand that share a cross-sectional boundary. The original intent of the set up was to capture the exact moment at which a bubble exploded. At that moment, the outline of the bubble retains its original shape, but also has a clearly ripped surface. However, after successfully capturing this phenomenon, it looked far less artistically appealing and interesting than simply observing the instant at which the two bubbles were sticking to one another. So, I ultimately chose this image. Also, I want to thank Aaron Coady for helping me set up this visualization.

The flow apparatus used for this experiment was a standard bubble-wand. An approximate drawing for this wand is shown below in figure 1. This is the only apparatus required to reproduce this image.

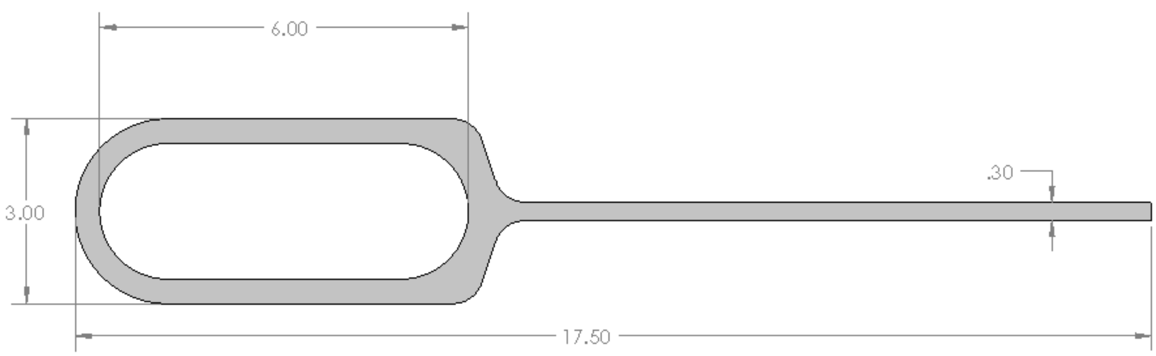


Figure 1

This wand is made of plastic and is less than a third of an inch thick, which gives it the ability to deform slightly. Also, the area surrounding the hole is serrated. The length of the hole, which in this case was about 6 inches, is the main factor on the apparatus itself that controls the size of the bubble. In order to produce bubbles with the device, the entire region surrounding the hole must be fully soaked in a soap and water solution. Typically, the solution is packaged with the wand, so it is unlikely that this solution will need to be prepared. After soaking the wand, a thin film will be visible across the hole. By either blowing on this film or waving the wand in the air, bubbles should come detached from the wand

and begin floating away. The speed at which the wand is waved or blown into is the main user-controlled factor in the visualization. Slower movement or blowing will yield larger bubbles and faster movement or blowing will yield smaller bubbles. The bubbles captured in my image are fairly large. The one on the left is approximately three inches in diameter and the other is about 3.5 inches in diameter. The physics behind this will be discussed later. At this point, the bubbles can be caught back on the wand. This is done by gently putting the wand under each bubble until it sticks. It is highly recommended that this visualization is performed either indoors or under steady conditions, because wind will make the bubbles move more than intended and difficult to catch. Once two bubbles are caught, observations can be made about their interface geometry and the picture can be taken.

From previous research, I gathered that bubbles are thin-walled, three-dimensional liquid shapes that enclose another fluid. Usually, they are spherical because for an expanding volume, a sphere has the smallest surface area. In the context of this visualization, the bubble itself is originally formed on the hole in the form of a membrane. The serrated edges of the wand allow the membrane to stick onto the wand while air is blown through the hole. Fast moving air will cause the membrane to break off of the wand quicker, thus resulting in smaller bubbles (Johnson). There is no definite mathematical formula that governs this relationship, but after repeated testing, this appears to hold true.

The scientific reason behind why these bubbles stick together lies in the chemistry of the soap and water. Soap molecules are bipolar: one end is hydrophilic (attracted to water) while the other is hydrophobic (repelled by water). So, when a soap bubble is formed, the hydrophobic portion ends up on the outside, as it is also attracted to air (Gruner).Then, when the bubble comes in contact with another bubble, the hydrophobic ends of the molecules in both bubbles become attracted to each other. Depending on how strong the wall of the bubble is, occasionally, this attraction will cause deformation in one of the bubbles. This is why there is a cross-sectional interface between the two, rather than just point contact. The amount of deformation is proportional to the diameter of the interface. In this case, somewhat significant deformation is seen, so the interface is about the same diameter as the smaller bubble.

No special visualization techniques are required to capture this image. My visualization was performed outdoors and used sunlight. The walls of the bubble can be sharpened in the image by increasing the amount of light, but no flash was used.

I used a Canon PowerShot SX230 HS, which is a standard point-and-shoot camera. The bubble was captured in burst mode (8 photos per second) and at a high shutter speed of 1/250 seconds because of the original goal of capturing the bubble right as it exploded. ISO-1600 was used, though this was simply circumstantial, and an f-stop of f/4 was used as well to compensate for the sunlight. Additionally, the lens' focal length was 10 mm and the image was taken from approximately five inches away from the bubbles. After post processing, the final resolution was 1584 by 1107 pixels to capture a field of view of approximately 6.5 inches by four inches. Photoshop was utilized to crop the image down to this size, but more significantly, to change the color and contrast. By changing the curves, the whole image was made green, which I believe makes the bubbles look like dew drops on a plant. Additionally, the brightness was decreased and the contrast was increased.

Ultimately, I do wish that the popped bubble looked more artistic, but I am satisfied with the appearance of the image I chose. I think that the cross-sectional interface between bubbles is a very intriguing phenomenon. As a next step, I would attempt to catch a third bubble on top of the two other bubbles to see how the cross section would be altered. Nevertheless, I think my main intent of creating an artistic image was fulfilled.

Works Cited

Gruner, Sol. "Ask a Scientist." n.d. 3 May 2012. <http://bigbro.biophys.cornell.edu/publications/c13_Gruner.pdf>.

Johnson, Juliet. *eHow*. n.d. 3 May 2012. <http://www.ehow.com/how-does_4596309_bubble-wand-work.html>.

Lohse, Detlef. "Physics Today." February 2003. 3 May 2012. <http://physicstoday.org/journals/doc/PHTOAD-ft/vol_56/iss_2/36_1.shtml>.