Team 2 Report
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4/4/11

Purpose:

This image was created for the second team assignment, although the work was done individually. The intent was to capture a sense of contrasting ideas and in this instant, soft over sharp. Initially, the goal was to freeze the popping of a soap bubble from the tip of an arrow; however, the camera used was not up to the task of capturing this very quick action. Instead, the surface tension and reflectivity of soapy water was controlled to create the final image.

Analysis:

The flow apparatus used was simply a tea candle holder with an arrow formed into the base, see Figure 1.

Figure 1: Items used to create image.

The height of the arrow tip and width of the candle holder are approximately 2 and 2.5 inches, respectively. The base of the arrow tip is a used tea candle that hot wax was dripped into to fill the base up to a ¼ inch. Before the wax hardened, the arrow base was placed upright and held steady to create the shown assembly. For the image, the arrow was placed inside the candle holder and then filled with the soapy solution which was purchased from Target. The next step was to coat the arrow tip with the extra soapy solution so the bubble would slip around it easier. The final step was to blow a bubble over the tip of the arrow until it came into contact with the candle holder and then subsequently joined together. The key to this was to pass the bubble over the arrow as slow as possible and to expect to need many attempts before success.

Bubbles are formed around pockets of gas, in this case air, and held together by an elastic film. The liquid solution that is the source of the bubble is important since a pure liquid, like water, alone will not hold. Instead, a surfactant, such as soap, needs to be added in order to lower the surface tension that allows the solution to stretch around the air pocket, shown in Figure 2 where F is the surface tension and P_1 and P_0 are the inside and outside pressures, respectively.

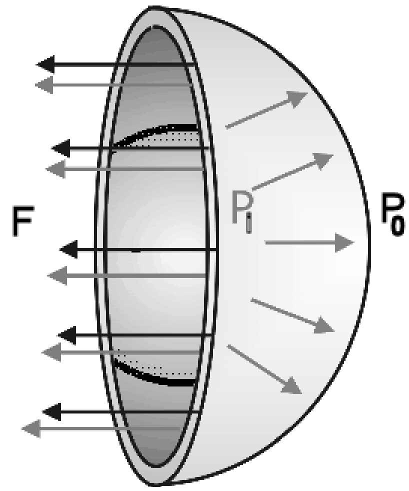

Figure 2: Diagram of the forces present on bubbles.

The equation governing the size of the bubble is a relationship between the pressure difference and the surface tension.

$$P_1 - P_0 = 2\gamma/r \tag{1}$$

Here γ is the surface tension of the bubble. At 20°C the surface tensions for water and soapy water are 0.073 and 0.025 N/m, respectively. Adding soap reduces the surface tension to a third of its original value allowing the solution more flexibility. Assuming a radius of 4 inches, or 0.1 meters, and an ambient pressure of 1 atm, or 100,000 Pa, the inside pressure of the pictured bubble is roughly 100,000.5 Pa showing that the pressures are essentially in equilibrium. Increasing the internal pressure or decreasing the external pressure would cause an increase in the bubble's radius. As long as the pressures are balanced then the flow can be considered stationary, however, there is some motion that can be seen within the film of the bubble. This motion is slight but likely caused by shear forces from the small air currents passing by the outer layer.

Essentially, the soap stabilizes the bubble. The key to a successful bubble is to keep the concentration of soap high so that the surface tension remains low. As the bubble passed over the arrow the pressure on the surface of the bubble would increase dramatically popping any bubble with surface tension that was too high. If the arrow tip were dry then it would grab some of the solution as the bubble passed over effectively increasing the pressure and also causing it to pop. Wetting the surface of the arrow tip reduces this effect and allows the bubble to pass over more effectively.

The next phenomenon seen in the final image is how the light reflects off the surface. When light hits the bubble it can reflect off the outer surface, pass through and reflect off the second surface, or enter the film of the bubble and reflect after bouncing around inside any number of times, seen in Figure 3.

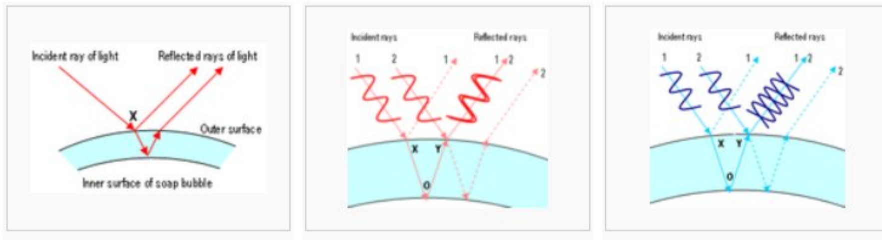

Figure 3: What happens to light on impact with a bubble.

The first outcome is seen in the image as the white light that is reflected as well as the red light given off by the red soapy solution at the base. Near the top of the bubble, a slight rainbow can be seen. This occurs as the bubble is thinning. As light hits the film, certain wavelengths are emitted at different thicknesses of the bubble surface giving off a rainbow.

Visualization Technique:

The materials used for this image were bubble solution purchased from Target, a tea candle holder, and an arrow tip which can be found at a sporting goods store. The bubble was formed inside where wind conditions could be controlled. The lighting used was 8, 70 watt bulbs lit from directly above the bubble. Also, there was a mirror next to the bubble which reflected additional light back onto the bubble.

Photographic Technique:

The camera used was a Nikon Coolpix L110, a digital "point and shoot" style camera. The image setting of the camera was on macro. The following table describes the camera settings for the image. The field of view was approximately 4 inches tall by 4 inches wide.

Shutter Speed	1/4 seconds
Max Aperture	3.6
Exposure	Normal
F-Stop	f/4.3
ISO	400
Focal Length	12 mm
Flash	None
Final Image Size	3072 x 2670 pixels
Distance from Object	Approx. 6 in.

Table 1: Description of camera settings used for the image.

Post-processing took place in Photoshop where the image was cropped and the brightness and contrast were adjusted.

Opinion of Image:

I was very pleased with the resulting image. The contrast between the soft, fragile bubble and the sharp, aggressive arrow tip seems to be obvious. The lighting allowed for a brilliant reflection off the surface of the bubble adding to the image's beauty. I think the image would benefit from more of the rainbow effect that is often seen in bubble reflections.

Sources:

Gutmann, Paul F. (1987). Bubble Characteristics as they Pertain to Compressive Strength and Freeze-Thaw Durability. MRS Proceedings, 114, 271 doi:10.1557/PROC-114-271

Taylor, Jean E. (1976) The structure of singularities in soap-bubble-like and soap-film-like minimal surfaces. Annals of Mathematics, Volume 103, pp. 489-539.

http://en.wikipedia.org/wiki/Soap_bubble

http://chemistry.about.com/od/bubbles/a/bubblescience.htm

http://labman.phys.utk.edu/phys221/modules/m9/surface_tension.htm