Get Wet

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Flow Visualization

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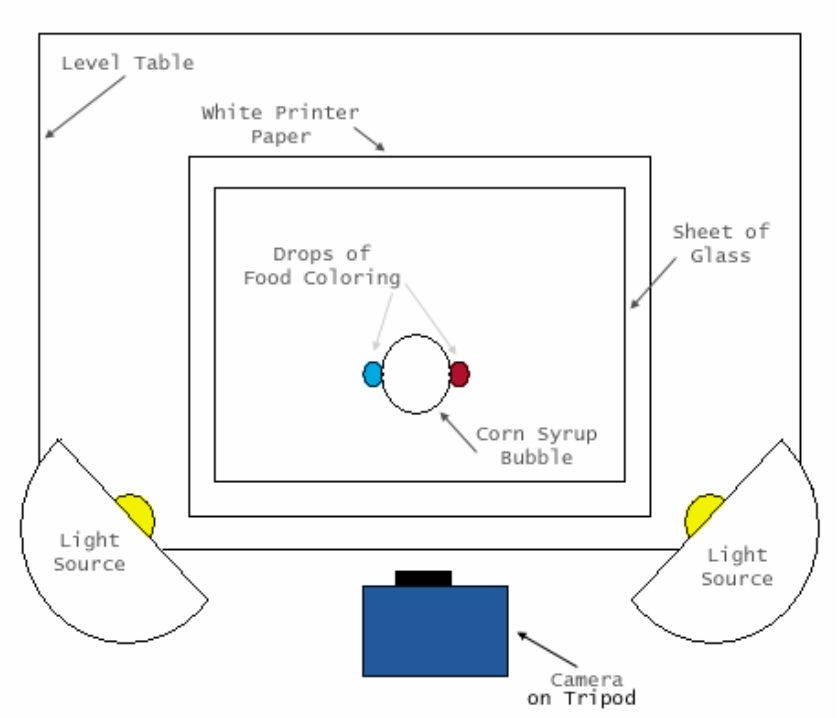
Images were captured of dye deposited on the edge of a bubble of Karo Light Corn Syrup as it propagated through the bubble. In several cases, multiple different pigments of the dye, food coloring, were introduced at positions roughly one hundred and twenty to one hundred and eighty degrees apart from each other around the bubble and mixture of the pigmented flows was observed. The various phenomena identified in the images not only illustrate interesting fluid motion, but also are very aesthetically pleasing. Thus, the subject was studied in more depth and over one hundred photographs were gathered. This interesting fluid flow came about because, originally, the viscous force of corn syrup between two layers of glass was being examined. As the top layer of glass was peeled back, the corn syrup exhibited a fingering pattern with very interesting responses to speed and length of specimen settling time. At one point, the corn syrup was being dyed with the pigments and the aforementioned phenomenon was observed. At this point, the fingering propagation was abandoned.

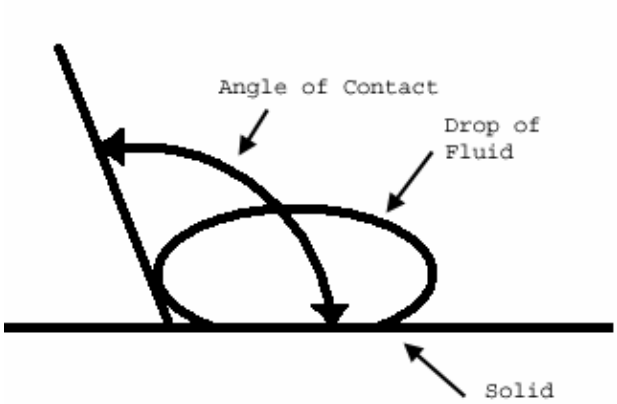
The experimental setup for capturing these images was very simple. A sheet of glass was placed on a white sheet of paper to provide a background of consistent color and composure. Both were set on a level table. A bubble of corn syrup was poured on the middle of the glass and one to three drops of different pigments of food coloring were introduced along the edge of the bubble. The size of the bubble greatly influenced how much propagation was observed. The specific corn syrup used was Karo Light Corn Syrup, which contains light corn syrup, high fructose corn syrup, salt and vanilla. This is essentially glucose. Meanwhile, the main ingredients in the food coloring, excluding the dyes, were water and propylene glycol. A camera was set up on a tripod above the bubble at a slight angle from vertical to obtain optimal camera position. The schematic for this setup is shown in Figure 1.

Figure 1: Experimental Setup Schematic



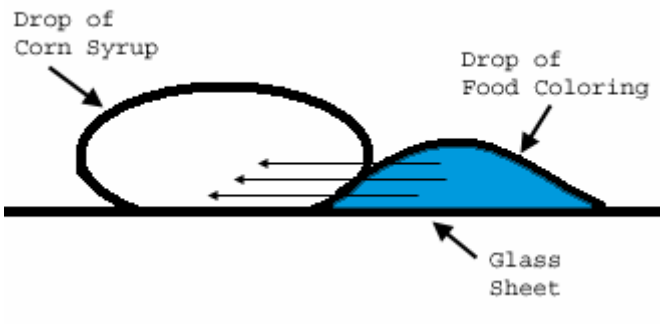
The basic flow is deeply rooted in surface tension effects, contact angle, and the wettability of the water/glycol solution and the corn syrup. The contact angle is described in the following figure.

Figure 2: Angle of Contact Schematic



According to http://www.lib.umich.edu/dentlib/Dental_tables/Contangle.html, the angle of contact for water on glass is 14 degrees. No data was found for the contact angle of glucose to glass. However, by observation the pigment seemed to move under the corn syrup so the physics of the flow might be described in the following manner.

Figure 3: Proposed Fluid Motion from the food coloring bubble into the corn syrup bubble



According to Fundamentals of Fluid Mechanics by Munson, Young, and Okiishi, "At the interface between a liquid and a gas … forces develop in the liquid surface which cause the surface to behave as if it were a 'skin' or 'membrane' stretched over the fluid mass … and are due to the unbalanced cohesive forces acting on the liquid molecules at the fluid surface." This means that the molecules on the surface of the corn syrup feel a net force toward the inside of the bubble. Hence, when the food coloring is deposited immediately adjacent to the bubble, the net force is exerted on it and it begins to propagate into the bubble of corn syrup. Further conclusions could be drawn with the exact values of surface tension and contact angle for glucose. Unfortunately, these values were unavailable.

The size of the initial corn syrup bubble in all cases was one to two inches in diameter. The bubble size and the shape continually grew as the diffusion took place with the maximum final length along the major axis of the bubble being about three inches. The final size was reached in approximately five minutes.

The food coloring in this scenario served a dual purpose. Not only did it diffuse through the corn syrup, but the color also provided a technique to visualize the flow. In each case, only one drop of each pigment of food coloring was applied. This corresponds to a circle about ¼ to ½ an inch in diameter per pigment. Several types of lighting were used in order to illuminate the fine aspects of the flow. These included the flash on the camera and the two standing lamps as shown in Figure 1. The standing lamps were equipped with 120 Volt, 150 Watt bulbs and were located about three feet above the image plane. The bulbs were pointed directly at the flow and covered with white cotton sheets in order to mask and diffuse the light.

All images for this project were captured on a 4.0 effective megapixel Nikon Coolpix 4300 digital camera. The field of view for all of the images is approximately four inches by three inches. In addition, the bubble was approximately twelve to fifteen inches vertically away from the lens of the camera. According to the digital monitor, the aperture setting was at f/4.8 and the shutter speed was 1/30 seconds. This camera is equipped with a 3x Zoom Nikkor and the corresponding focal length range is 8 mm to 24 mm. After image capture, a small amount of Photoshop processing was performed. In all photographs an Auto Levels filter was used to achieve a more aesthetically balanced image. In images Hayworth_GetWet1_2 and Hayworth_GetWet1_4, the background was altered from a grainy off white color to pure white for greater contrast and image impact. For the high quality images, the pixel resolution was changed to 300 pixels per inch and the file was exported as a .tif.

Observing the fluid flow has lead to the conclusion that the pigmented water diffuses underneath the corn syrup. I would like to learn more about the methods of fluid transfer as well as why specific types curls in the flow are created such as the simple curl as opposed to the complete loop and what type of concentration gradients cause these types of flows. In general, I completed my intentions of capturing a new and interesting yet aesthetically pleasing flow. There were many things I found intriguing about the flow including the variety of shapes the corn syrup bubble as a whole expanded into as well as the differences in diffusion based on color. Overall, blue seemed to reveal the most interesting flow elements and details, followed by green, red, and then yellow. I really like the color composure and the simple beauty of my images. In fact, they are going to be the new living room decoration in my apartment. However, I still have a few complaints. My main complaint about the images is the difficulty I had in trying to achieve proper lighting and minimal reflection off of the glossy corn syrup. In addition, out of more than one hundred images taken, very few were in focus enough to resolve the fine details of the flow. Therefore, with a camera that is better adapted to working on small scales I would like to create a time lapse of the pigment development in the bubble. I feel with more time and different resources I could explore this subject more completely.