Get Wet Report
Andrew Beat
2/11/11

Purpose:

The image submitted is from the first, individual project entitled "Get Wet" designed to introduce the capturing of fluid phenomenon. This particular image was taken with the intention of showing how differences in densities and viscosities would affect fluid flow. Initially, the intent was to show water standing on syrup in a bubble but the friction between the fluids was not enough and the water droplets were collapsing immediately. After repeated attempts the water began mixing with the syrup giving off very interesting color schemes and the decision was made to abandon the intended outcome for capturing a bubble rising through the colored syrup.

Analysis:

The flow apparatus consisted of a small candle holder filled with a mixture of corn syrup and dyed water. The dimensions of the holder can be found below.

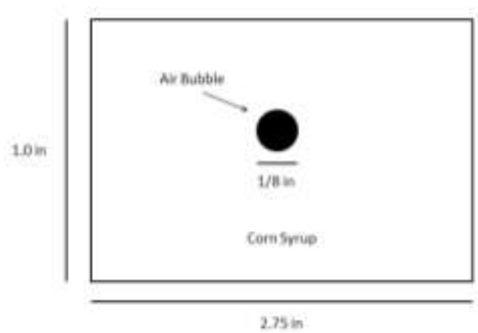

Figure 1: Diagram of flow apparatus.

In order to increase the syrup's viscosity it was placed in the freezer for 30 minutes prior to use. While the syrup chilled, two batches of tap water were colored, one red and one blue. Using an eye dropper, a few drops of each water color were dropped on the surface of the syrup. Because of density differences and the surface tension of the syrup the water did not immediately mix. The dropper was then used to perturb the surface of the syrup allowing the water to mix within the top half of the syrup creating the scattered lines visible in the background of the image. To create the bubble, air was sucked into the dropper and then released at the bottom of the candle holder beneath the syrup and water mixture. Once the bubble was released from the dropper buoyant forces caused it to rise to the surface of the mixture.

To first analyze the observed flow the Reynolds number was calculated. This was done using the equation proposed in Oliver and Chung (1986):

$$Re = \frac{2Ua}{\nu} = \frac{2 \cdot 0.0254\left(\frac{m}{s}\right) \cdot 0.0015(m) \cdot 1380\left(\frac{kg}{m^3}\right)}{75 \cdot 10^{-3}\left(\frac{kg}{m \cdot s}\right)} = 1.4 \tag{1}$$

Where *U* is the velocity of the flow (or bubble in this case), *a* is the diameter of the bubble, and ν is the kinematic viscosity of the corn syrup.

Because the bubble is rising with a very low Reynolds number there is not recirculation of flow behind the bubble. This is shown in the image by the lack of eddies or wakes in the bubble's path. This phenomenon occurs when the flow across the sphere is slow enough that no boundary layer separation occurs. A model of this can be found in Figure 2.

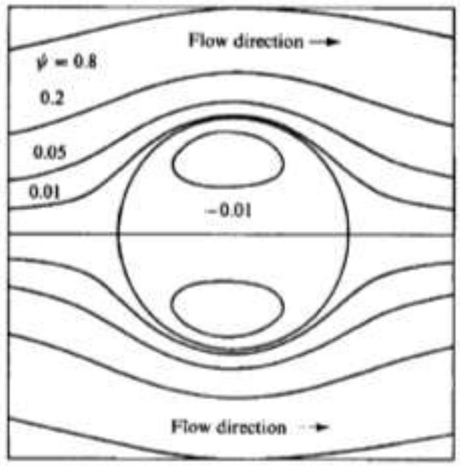

Figure 2: Flow around a gas sphere with Re=1.
(Oliver and Chung 1986)

From the figure it can be seen how the streamlines meet the sphere at the stagnation point, compress to flow around the side, and finally realign on the backside without any eddy or wakes forming.

Another phenomenon observed due to low Reynolds flow is the lack of internal circulation within the air bubble. Typically, with two viscous fluids, significant shear forces are found at the interface between the fluids which will cause the fluid with more momentum to transfer some of its energy to the other in the form of an internal vortex. This slows the flow around the sphere and causes internal circulation. In the image, the flow is slow enough that the corn syrup is able to pass by the interface of the bubble without "pulling" on it to cause recirculation.

The difference in fluid densities between the syrup and the air also explains the shape of the bubble. As the bubble frees from the dropper it took a spherical shape, however, as it ascends the syrup pushes back on the bubble forcing it to "squish" into the shape in the image. Because the syrup's density is much greater than air's it forces the bubble to deform in order to conserve momentum.

Finally, it is beneficial to consider the light visible in the photograph. Despite green being the only light created in the image, more than that is seen. This is because the colored water mixed in with the syrup absorbs certain wavelengths of light while letting others pass through. In this instance, the red and blue water mixed at the top of the container to create purple which blocked the green from passing through. In contrast, at the bottom of the container, the syrup remained in its pure, clear state so the green light was able to be seen. Finally, almost all light was scattered inside the air bubble so it looks almost black.

Visualization Technique:

This image was created using; dyed water (blue and red), standard corn syrup, a round candle holder, air, an eye dropper, and a lamp covered in a green, transparent plastic wrapping. The image was taken inside a completely darkened room where the only light available was that coming from the lamp. A black towel was used as a backdrop; however, it did not seem to matter due to the closeness of the image. The green lighting was achieved by using a green wrapping designed for Easter baskets found at a local craft store to cover the light bulb of the lamp. No flash was used. The candle holder used was a standard, clear tea candle holder that was circular in shape. The room temperature was about 70 F which did warm the chilled corn syrup but the short travel distance of the bubble showed no recognizable change in velocity due to the decreased viscosity of the warmer syrup.

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 0.75 inches tall by 0.5 inches wide.

Shutter Speed	10/300 seconds
Exposure	Normal
F-Stop	f/4.5
ISO	136
Focal Length	15.1 mm
Flash	None
Final Image Size	1566 x 2124 pixels
Distance from Object	Approx. 1 cm

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

Once the image was finished, minor editing took place. Using Photoshop, the image was cropped to its final dimensions and the "Stamp" tool was used to reduce the amount of background visual noise that distracted viewers from the main focus of the image.

Opinion of Image:

The image submitted reveals how fluid flow around a sphere at very low Reynolds numbers as well as how conservation of momentum comes into play for fluids of different densities. My favorite parts of the image are the clearly visible streamlines behind the path of the bubble, although, I wish the lines in front (or above) the bubble were more easily seen. I also like the color distribution of the image. One of my concerns coming into this project was my severe lack of artistic and photographic skills and how was that going to affect the quality of my image. I would like to improve the image by removing the eye dropper from the image and getting the streamlines above the bubble to be more visible. It would also be interesting to see how using different fluids to create the bubble would change the fluid flow. If a bubble could be given enough force to create a Reynolds number much larger than 1 it would be interesting to capture any eddy or wake effects behind the path.

References:

Chester W. and Breach D.R. (1968) On the flow past a sphere at low Reynolds number. Journal of Fluid Mechanics, vol. 37, pp. 751-760.

Oliver D.L.R. and Chung J.N. (1986) Flow about a fluid sphere at low to moderate Reynolds numbers. Journal of Fluid Mechanics, vol. 177, pp. 1-18.