

Jason Ortmann  
Flow Visualizations  
MCEN 4228-010

### Assignment 1: Get Wet

Flow phenomena exist in all aspects of life, especially where you least think of it. Concepts such as buoyancy and surface tension explain the physics behind many things including ships sailing across a body of water. The goal of this experiment was to capture both of these concepts in one image using mediums that likely no one would consider extraordinary. The goal was developed while observing the interaction between several fluids and seeing how easily these phenomena can be seen.

The fluid motion was created by adding a much more viscous and dense fluid to a combination of other fluids at a steady rate. The sketch below shows the setup for the experiment:

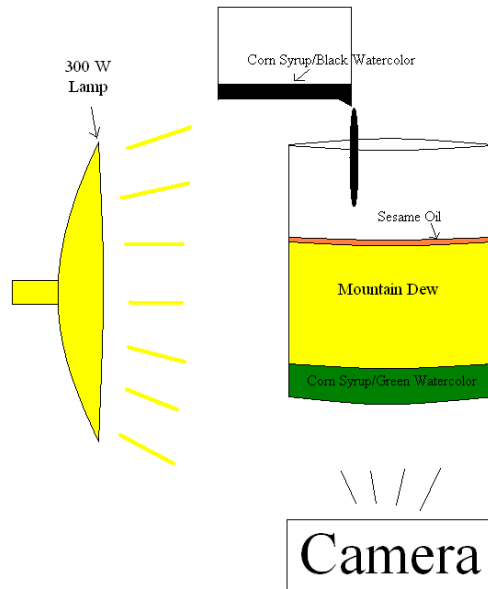


Figure 1- Experiment Apparatus

The fluid flows that were captured in the image include the buoyancy effects, which can be modeled by fluid flowing over a sphere, and the forces due to surface tension. As the corn syrup is dropped into the container, some of the sesame oil from the top is dragged down, where it then makes its way back to the top buoyancy. The image below shows the basics of flow over a sphere as well as the equation for the Reynolds number describing the flow.

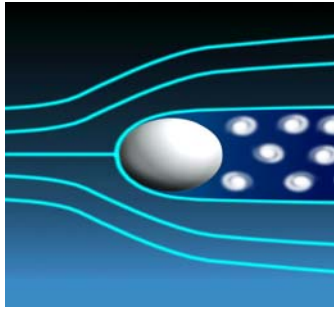


Figure 2 – Laminar Flow Over Sphere (1)

$$Re = \frac{\rho V D}{\mu}$$

Equation 1 – Reynolds Number (2)

Assuming an oil sphere diameter of approximately 3mm (.003 m), the velocity to be about .1 m/s and the viscosity ( $\mu$ ) and density ( $\rho$ ) of the Mountain Dew to be approximately that of water, the Reynolds number of the experiment was found to be  $1000 \cdot .1 \cdot .003 / 1.5E-3 = 200$ . Such a small Reynolds Number tells us that the flow as the bubbles rise to the surface is laminar. Lastly, surface tension is what causes the denser corn syrup to temporarily be suspended at the top. Surface tension is the net force that results from unbalanced intermolecular forces on the surface as shown in the figure below.

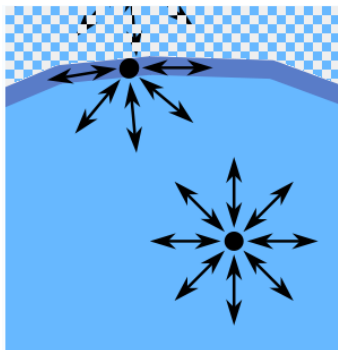


Figure 3 – Surface Tension (3)

For this experiment, the corn syrup, which would otherwise sink below the rest of the liquids, will be temporarily suspended at the top due to the surface tension forces.

In order to visualize these concepts, everyday materials were utilized. All fluid was held within a typical 16 ounce clear drinking glass. The bulk of the liquid was 6 ounces of Mountain Dew. The fluid which was suspended due to surface tension was corn syrup died with watercolors. Finally, the fluid experiencing the buoyancy effects was about a tablespoon of pure sesame oil. Buoyancy was also seen in the carbonation,  $CO_2$ , escaping from the soda. All materials were already contained in the kitchen, except for the Mountain Dew, which was purchased especially for the experiment. Due to the quickness

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of motion within the field of view, lighting was crucial to getting the right shot with such a high shutter speed. To get a sufficient amount of light, all indoor lights were turned on, and an additional source of light (300 W) was placed directly to the left and about a foot away from the desired image. The ideal source of light would be directly above, but due to the light source, this was not possible to achieve in a safe manner.

Due to cost of materials, the phenomena were observed on a particularly small scale. The field of view of the original photograph was approximately 4x6 inches. A Nikon D80 digital camera took the photograph using a Nikon DX lens with an aperture range of 1:3.5-5.6. The lens focal length was 127mm, just in the cameras range of 18-135mm. The camera was set to take the highest resolution picture possible, with an original image size of 3872 pixels wide by 2592 pixels high. The final image was cropped to a size of 1432 pixels wide by 1972 pixels high. Shutter speed was slightly compromised in order to get a sufficient amount of light, with a shutter speed of 1/125 seconds, and F/ number of 5.6, and ISO value of 100. Once the image was taken (Figure 4), the area of focus and the colors were enhanced using Adobe Photoshop CS3. The only color altering effect used the “curves” adjustment. Using curves, the whole image was made brighter, with a slight emphasis on the mid range brightness in order to bring out to colors. After that, the only other alteration was cropping the image into the final desired product (Figure 5).

When looking at the final product, the image respectably shows both buoyancy and surface tension in a very visually stimulating way. I am very pleased with the colors I was able to capture in order to contrast the different fluids. However, I am somewhat disappointed in the amount of focus in some parts of the image. The amount of fluid motion along with the inadequate amount of light resulted in a slight amount of motion blur of the falling fluid. However, the effect of both buoyancy and surface tension are apparent in the photograph. As the Mountain Dew bubbles due to carbonation, the gas escapes the fluid because of its lower density. The bubbles are pushed downward with a force equal to its mass x gravity, while a larger vertical buoyant force acts upward and causes the bubbles to rise. This vertical buoyant force is equal to the weight of the fluid it displaces (4). Because the density of the bubbles is negligible when compared to that of the fluid (which is assumed to be close to that of water), the buoyancy force is estimated from the equation below:

$$\text{Force} = \text{Density of Water} \times \text{Volume of Water} \times \text{Gravity}$$

Equation 2 – Buoyant Force

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Using Equation 2, the buoyancy force was calculated to be  $1000\text{kg/m}^3 \times \frac{4}{3}\pi \times (.001\text{m})^3 \times 9.81\text{m/s}^2$  which equals  $4.11 \times 10^{-5}$  N. This is the vertical force accelerating the bubbles through the liquid. Due to the amount of corn syrup sitting at the bottom, it is clear that it is denser than the Mountain Dew. However, the surface tension described earlier is suspending a portion of the liquid at the surface. Overall, I partially fulfilled my intent in that I was able to capture the surface tension, but would like to improve on the method to better capture the buoyancy effect. If I were to try to completely fulfill my intent, I would make improvements based on a few things I observed before began taking pictures. At the beginning, I noticed that after pouring the corn syrup into the mountain dew, carbonation would become trapped under and have to flow through the syrup. Once escaped, the bubbles would pull up some of the corn syrup due to the viscosity of the fluid. Capturing that image would better represent the desired phenomenon since it would show the bubbles in an upward motion due to buoyancy effects. However, I am still very satisfied with my final image, and feel that I was able to capture the fluid behavior in a very interesting way.

#### Works Cited

(1)

"Why does a golf ball have dimples?" Cislunar Aerospace, Inc., Copyright © 1997-1998

<http://www.fi.edu/wright/again/wings.avkids.com/wings.avkids.com/Book/Sports/instructor/golf-01.html>

(2)

Smits, Alexander. A Physical Introduction to Fluid Mechanics. New York: John Wiley and Sons, Inc., 2000.

(3)

2006-05-18 11:07 [Roland.chem](#) 300×304×8 (14982 bytes) \* *Bildbeschreibung: Wasser in Tropfen und an der Phasengrenze* \* *Quelle: own made* \* *Fotograf/Zeichner: [[Benutzer:Roland.chem|Roland.chem]]* \* *Datum: 18.4.06* \* *Sonstiges*

(4)

Frank M. White, "Fluid mechanics", in AccessScience@McGraw-Hill  
<http://www.accessscience.com>, DOI 10.1036/1097-8542.262300

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Appendix A



Figure 4 – Original Photograph

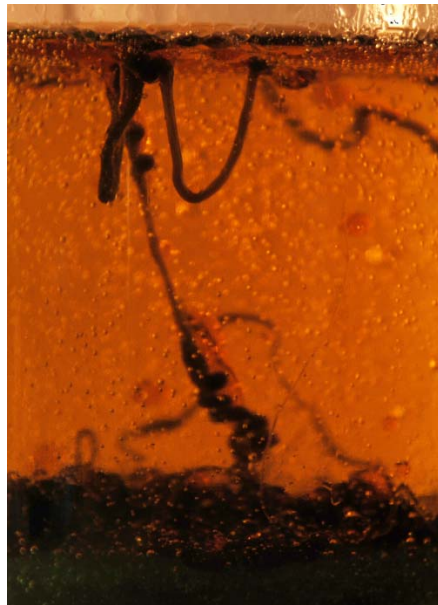


Figure 5 – Final Image