Get Wet 1

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Mechanical Engineering

Elmer's Glue & Dawn Soap

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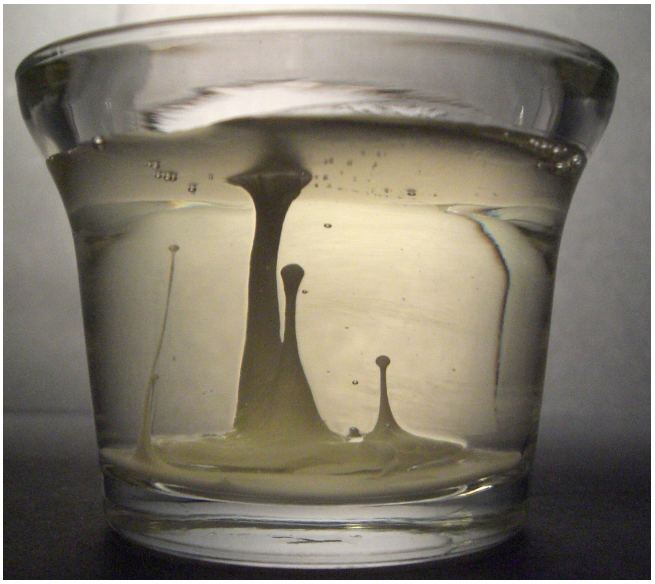


Background

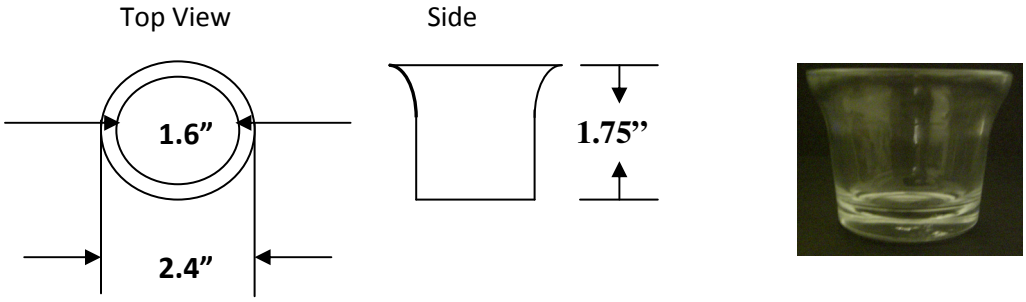
This project deals with the interaction of either air, water, or any combination of fluids and the physics involved in their interactions. For this project, I wanted to explore viscous forces versus buoyant forces and the materials I experimented with included Elmer's glue, food coloring, highlighter ink, Dawn soap, and hydrogen peroxide. After multiple rounds of trial and error with the different materials, Elmer's glue and Dawn soap were the materials used for the final image. It was discovered that the viscous forces dominated the fluid flow, which will be discussed in the Fluid Flow Analysis.

In addition to creating an image in which the physics of fluid flow could be discussed, I also wanted an artistic image that would transform a person's quick glance into a more serious thought. For me, my thought got my imagination thinking and it reminded me of a planet. While this thought cannot be explicitly explained, it is the spark of imagination I hope this photograph creates for people.

Apparatus

The apparatus used in the final image was a circular drinking glass. Figure 1 depicts the glass's dimensions as well as an actual image of the glass.

Figure 1



Fluid Flow Analysis

The density of Elmer's glue is 1.07 g/cm^3 [1] the density of Dawn soap is .932 g/cm^3 [2]. From these two numbers alone, the expectation of the overall interaction will be that the glue sinks. As seen in the final image, the glue does sink and spheres of glue begin to rise back to the surface. The spheres of glue are able to travel upward because of the formation of small air bubbles, which occurred while pouring the Elmer's Glue into the Dawn soap. As the Elmer's glue displaced the Dawn soap, air rushed in, became trapped, and created air bubbles. Some of these air bubbles remained with the glue as it sunk to the bottom and due to buoyant forces, the air bubbles began to slowly rise back to the top. Also, after letting the Elmer's glue and Dawn

soap sit in the apparatus for two full days, it was evident they did not create a homogeneous mixture and therefore are immiscible when combined.

To obtain an idea of the physics occurring, it is necessary to first calculate the Reynolds number to determine the type of flow.

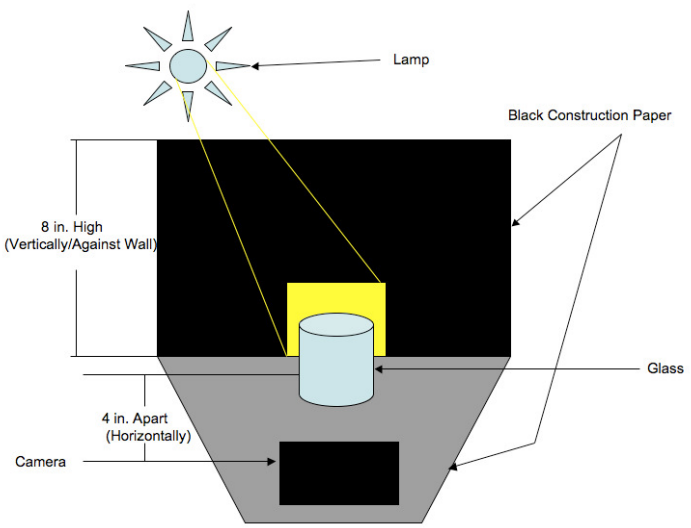
Reynold's Number: With a velocity of approximately 0.6 cm/s , a density of 1.07 g/cm^3, a length of 5 cm, and a kinematic viscosity of 25 g/cm*s, a Reynolds number of 0.14 was calculated for glue. This low number represents not only Stokes flow, a type of laminar flow for which Re <<1, but also indicates the two main forces involved are viscous forces and pressure forces. For Stokes flow, the spheres always remain spherical and this is due to Eotvos's number, which is a dimensionless number representing surface tension. Also for Re <<1, the flow is attached to the spherical bubble and there is a very weak wake behind the sphere [3]. This weak wake creates no visible recirculation of the flow behind the sphere and explains why the there is a stream of glue attached to the rising sphere. It is important to note that since Dawn soap is a surfactant, this will most likely increase the effect viscosity will have on the fluid flow [3]. We can verify viscosity as the dominating force by calculating Grashof's number.

Grashof's Number: With gravity at 9.81 m/s^2, the thermal coefficient of expansion of glue at 6.7 * 10^{-4}/k^3 [4] temperature difference of 7K, length of .0508 m^3, density of 1.07*10^6 g/m^3, and an absolute viscosity of 2.5 *10^7 , Grashof's Number was 1.1. Grashof's number is a ratio between the buoyant forces and viscous forces. Obtaining a small value for Grashof's number indicates that the viscous forces are the dominating forces and explains the air bubbles long rise (~ 60 s to 90 s) toward the surface.

Lighting

The final lighting scheme involved no flash, black construction paper around the sides and back of the apparatus and a 60W lamp light behind the apparatus. This scheme worked very well because with just the lamp light placed behind the apparatus, there was enough light to show the fluid flow. I also did not have to worry about having to use a flash and have reflection spots in the image. Figure 2 is a PowerPoint sketch of the lighting setup.

Figure 2



Materials

Material	Amount Used
Elmer's Glue-All (Multi-Purpose Glue)	Squeeze glue bottle with medium pressure and hold for 8 seconds
Dawn Soap	Fill up apparatus until glass begins to flare outward

Photographic Technique

Focal Length	6.20 mm
Size of the Field of View	~ 15 cm
Distance from Object to Lens	4 inches
Type of Camera	
Digital	Casio Exilim EX-Z700
Width X Height (Original)	3092 X 2304
Width X Height (Cropped)	1772 X 1572
Exposure Specs	
Shutter Speed	1/80
Aperture	2.6
ISO	400

iPhoto

I used iPhoto to crop the image, but did nothing else to the image.

Final Thoughts

Initially, I liked my image a lot with regards to what was occurring visually. To be honest, I liked the image even more after investigating the physics. It is as if you have connected to the image and understand it on a deeper level. If I were to recreate the image now that I understand the physics of the interaction, I might try to inject a dye into the glue to produce a more visual boundary line between the two fluids. I also would like to create an image in which they are tons of very, very small air bubbles and against a black background, I believe it would appear as space.

Overall, I am very pleased with my final image and have learned a lot about the fluid flow within my image.

References

[1] http://www.elmers.com/msds/ME375_C.HTM

[2] http://hypertextbook.com/facts/2005/VirginiaAllard.shtml

[3]

http://books.google.com/books?id=7FDbB7VjxkQC&pg=PT44&lpg=PT44&dq=stokes+flow+bubble+wake+streamline&source=web&ots=tTirIlRt-_&sig=37ZONeLu37kvj7mhaLiSQojgDdU

[4]

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