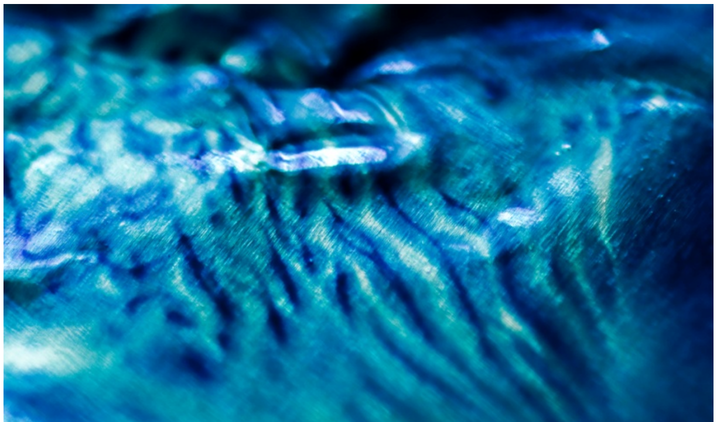
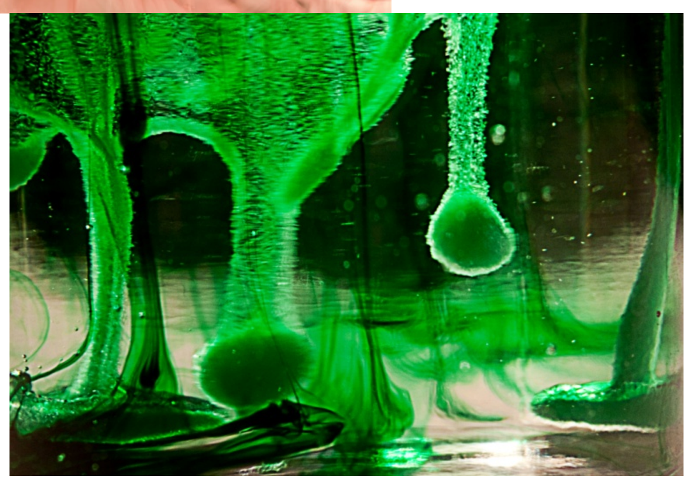
MCEN-4228-010
Flow Visualization
Group Project 01 Report





By Group Phi
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Introduction

The purpose of the first group project is to observe the behavior between fluids of different densities. Specifically, the group chose to examine the interface between the fluids and observe any other phenomena that occurred, and attempting to capture diffusion between the two layers. Diffusivity is the physics with the transport of molecules in a mixture. The driving force of diffusivity is a concentration gradient of molecules; where a higher concentration of molecules will "diffuse" to a lower concentration over a period of time. The group attempted to illustrate the phenomena. After a substantial number of photographs, the group individually chose final images based on two basic Flow Visualization criteria, the image exhibits a flow of physics and aesthetics aspects of the photograph.

Flow Apparatus

To create the results similar to the photograph, the group used standard, store bought corn syrup for the high density fluid, and used a variety of lower density fluids. The lower density fluids included water, rice vinegar, 3% by volume hydrogen peroxide, and 200-proof ethanol which were all dyed using food coloring. All fluids were at room temperature when the photographs were taken. Each group member chose to study a separate image. The flow apparatus differs slightly from one image to the next; however, the basic flow apparatus is the same. Nevertheless, the flow apparatus will be discussed in detail in the next section. Below is a diagram of the setup that created the final images. Figure 1a is a diagram of the side view, and figure 1b is a view from the top.

Figure 1a: Side view of setup

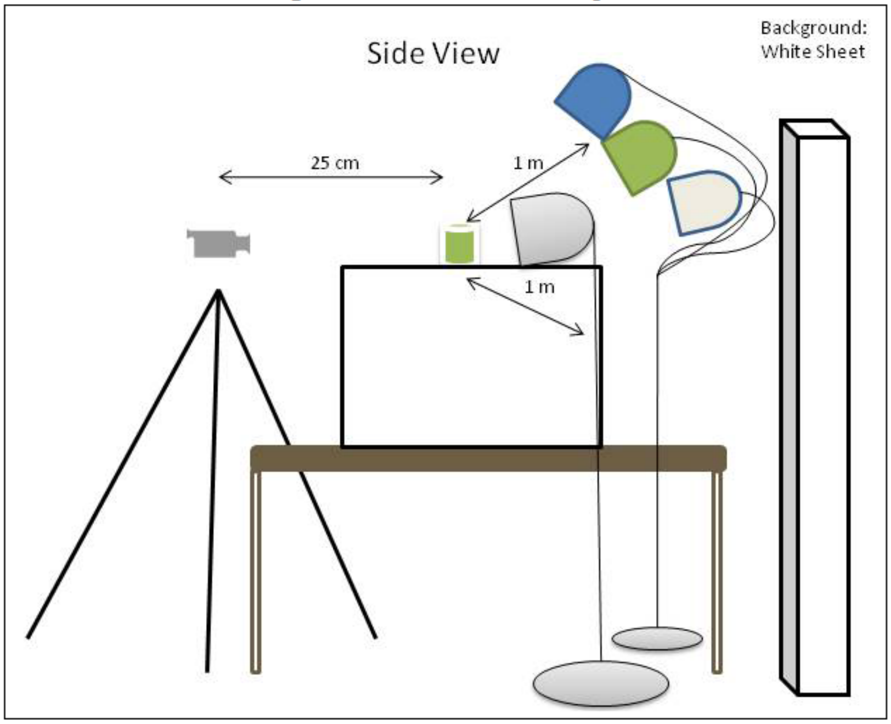
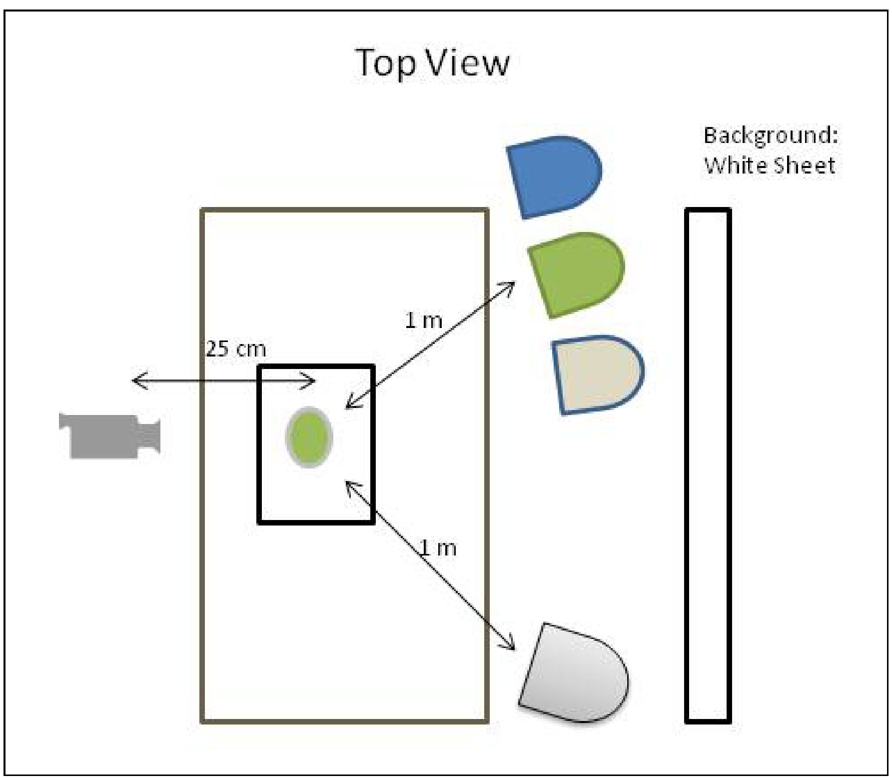
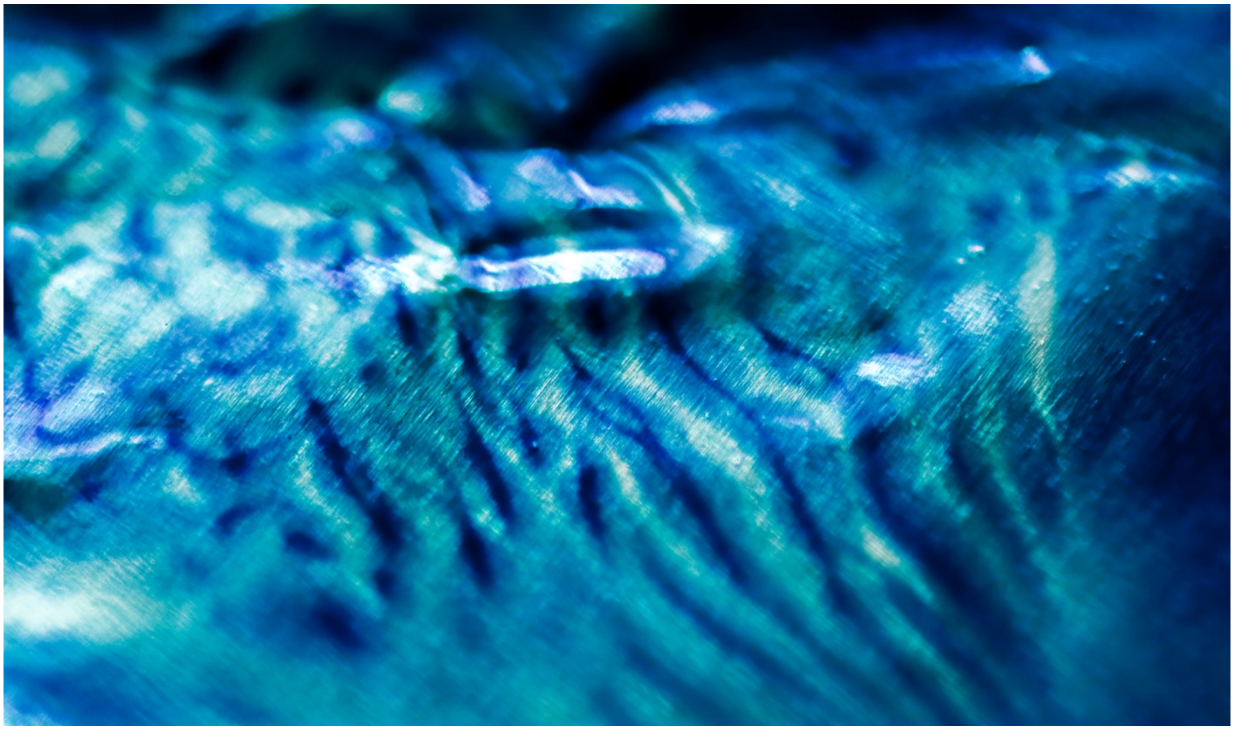


Figure 1b: Top view of setup



Visualization Techniques and Flow Descriptions

1.1



By Kane Chinnel

The group focused on capturing the diffusion between two fluids with different densities. We mainly focused on the interaction between the interfaces of fluids. The first test was diffusion between distilled tap water and corn syrup at room temperature; however, the process took far too long. In an attempt to decrease the time it took to diffuse, other common household chemicals were used. These chemicals are 200-proof ethanol and 3% hydrogen peroxide. A ceramic plate was covered with Reynolds Wrap aluminum foil to reflect light through the fluids. Then a drop of corn syrup was placed on top. After 30 seconds, the corn syrup would even out. Afterwards, well mixed dyed ethanol or peroxide was placed next to the corn syrup in hopes that for a quicker diffusion time. The Figures below is a list of the fluid properties and an estimated Reynolds number as the corn syrup diffused into the less dense fluids. The diffusion can be modeled using Fisk's first and second laws of diffusivity. The first law relates the diffusive flux to the concentration field. His second law predicts how diffusion causes the concentration field to change with time. For the case of the Flow Visualization experiment, the first law:

$$n(x,t) = n(0)\ \mathrm{erfc}\left(\frac{x}{2\sqrt{Dt}}\right)$$

Calculates how far the density has propagated in the x-direction by diffusion in time t. Time t=15s, travel length D= 0.025m, and n(0) is the density of the corn syrup at time t= 0s. The equation provides a generalized differential equation of density as it moves through x distance with respect to time. At the interface between the two fluids, the of corn syrup density increases as it diffuses into the ethanol alcohol.

Table of fluid properties

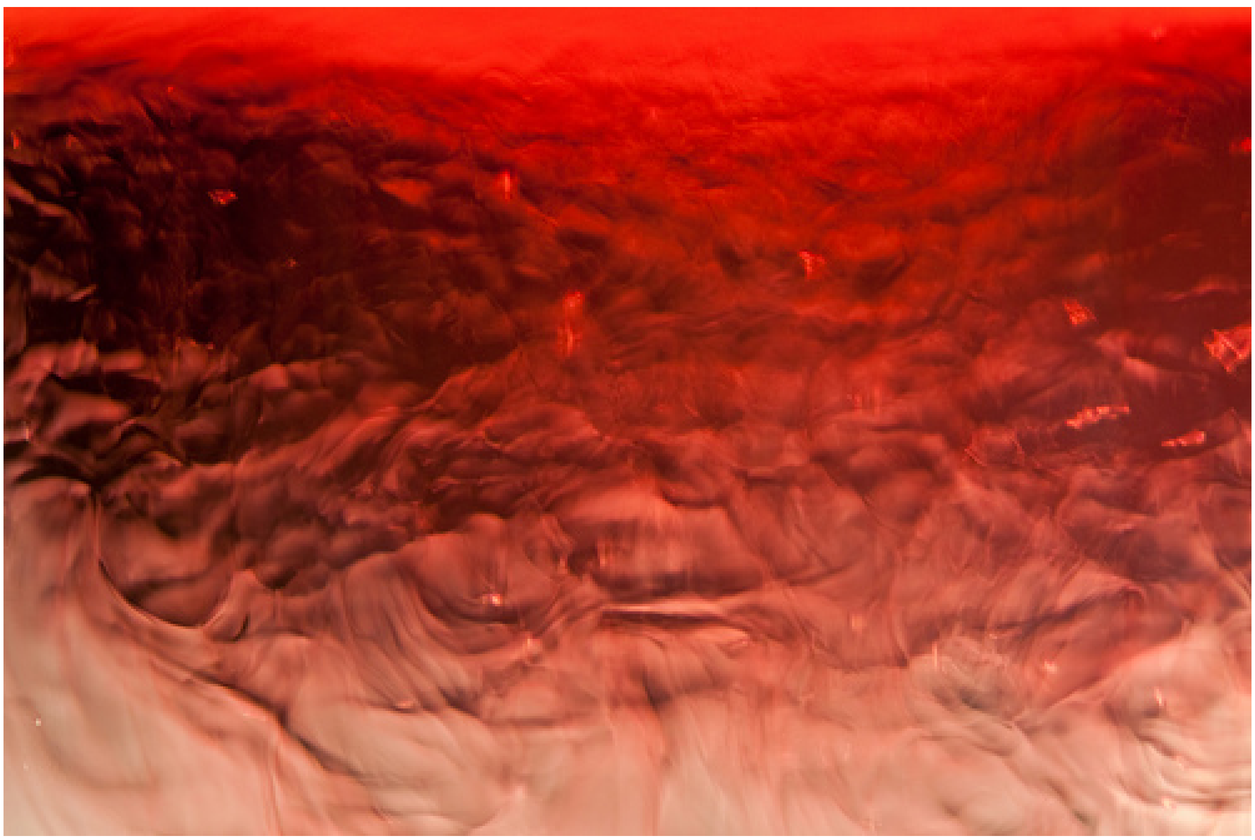
	Corn Syrup [1]	Hydrogen Peroxide [2]	Ethanol [3]
Density :	1360 Kg/(m^3)	1004 Kg/(m^3)	789 Kg/(m^3)
Dynamic Viscosity:	24 Kg/(m*s)	1.04*10^-3 Kg/(m*s)	1.2*10^-3 Kg/(m*s)

Estimation of Reynolds Number

Density:	1360	Kg/(m^3)
Velocity (estimated):	0.00125	m/s
Length:	0.025	m
Viscosity:	0.00104	Kg/(m*s)
Re =	40.86538462	

The final image displays the diffusion of denser corn syrup into a lesser dense blue dyed ethanol mixture. Time lapse is much quicker than water; the photograph was taken 15 seconds after the two fluids had been mixed. The low Reynolds number indicates very laminar and stable flow throughout the concentration gradient. Photoshop was used to enhance the flow and display, in detail, the concentration gradients. A high pass filter was overlaid on top of the original image, and set to 23.3 pixels. Afterwards, picture cropping brought the raw image down to a manageable size. The original image size is 4288 x 2848 pixels down to 3859 x 2278 pixels. Other than the high pass filter and picture cropping, no other photo enhancements were done in Adobe Photoshop.

1.2



By Corey Davis

This image was created for the first group project. In this image I was trying to illustrate the odd temperature gradient looking forums that were created when I mixed hot water with corn syrup.

The flow apparatus used in this project was very simple. I placed corn syrup into a shot glass on top of it I put a few drops of rubbing alcohol diluted food coloring. After observing this for a while I decided to put hot tap water roughly 120ºF and placed saran wrap over the surface so I could mix up the liquids without them spilling. After the liquids started to separate again the corn syrup began to form clear cloud like formations.

For this assignment I used corn syrup, hot tap water, and alcohol diluted food coloring. I had two main sources of lighting, all incandescent. I back lit the subject and placed it on a white box so the light would reflect back and through the entire shot glass.

Not too much was done post processing wise in this photo. I simply removed dust particles from the outside of the glass and adjusted the levels of the image to better bring out detail. I also applied an unsharpened mask in order to show the edges of the "clouds"

I think this image reveals what I saw when I decided to take the picture. It was somewhat difficult to get the camera to see exactly what I saw. I like how the image resembles fire. I'd like to know what this effect is. I've seen it before when I'm mixing sugar into hot water but I wasn't able to find any information on this phenomena

1.3

By David Ramirez

The intent of the image was to explore relationship between corn syrup and food coloring. An initial thought was that the food coloring would diffuse throughout the corn syrup. The image was a part of a series of images captured by group Phi. This was the first time the group worked together. This particular image was one of the last images captured. Though the intent was to use only corn syrup and food coloring, vinegar and baking soda were also used.

A shot glass was filled with approximately .25 ounces of green food coloring and then 1.25 ounces of corn syrup was added. The food coloring is not a dense as the corn syrup so the dye ascended to the top of the glass. The food coloring took approximately ten minutes to settle on the top of the corn syrup. After this settling was realized, baking soda was added to the dye as well as rice vinegar. There are two reactions that occur between rice vinegar and baking soda. The first reaction is an acid base reaction. The second reaction is a decomposition reaction. When the two ingredients are mixed, hydrogen ions (H^+) from the vinegar react with the bicarbonate ions (HCO_3^-) from the baking soda to from carbonic acid (H_2CO_3).

$$H^+ + HCO_3^- \text{--->} H_2CO_3$$

The carbonic acid then decomposes immediately into carbon dioxide gas (CO_2) and water (H_2o).

$$H_2CO_3 \text{--->} H_2O + CO_2$$

The complete reaction is written below.

$$NaHCO_3\ (aq) + CH_3COOH\ (aq) \text{---->} CO_2\ (g) + H_2O\ (l) + CH_3COONa\ (aq)$$

The reactions between the rice vinegar and the baking soda formed a precipitate in the corn syrup/food dye concoction. The image was captured as the precipitate floated to the bottom of the glass. The density of corn syrup is estimated to be 1.360 g/cm^3. The density of green food dye is estimated to be approximately the same as tap water, 1.000 g/cm^3. It is difficult to report a density for the precipitate but it is known that it is larger than 1.360 g/cm^3. This can be stated because the precipitate sank to the bottom of the shot glass that was filled with corn syrup. Denser fluid will sink while less dense fluid will rise.

Reporting a Reynolds number is difficult. It is estimated that the velocity of the precipitate is .635 cm/s. It is estimated that corn syrup has a dynamic viscosity of 20 g/cm*s. The diameter of the shot glass is approximately 2.54 cm. The Reynolds number of approximately .1097 was calculated for the precipitate. With such a low number the flow of the precipitate can be said to be a Stokes flow. Stokes flow is a type of laminar flow where inertial forces are very small compared to viscous forces[1]. The typical Stokes flow has a Reynolds

[1] Happel, J.& Brenner, H. (1981) *Low Reynolds Number Hydrodynamics*, Springer

number much less than one, Re>>1. It seems surface tension would account for the spherical shape of the reaction. The baking soda that is not completely broken down in the image is combining with the corn syrup and sinking to the bottom of the glass.

Assuming that corn syrup has a coefficient of thermal expansion of $6.3*10^{-4}/k^3$ and a temperature difference of 2 K it can assumed that the Grashof's number is 1.013. Grashof's number is a ratio between buoyant forces and viscous forces. A lower number means that viscous forces are the dominate forces[2]. The low Grashof's number explains the slow sinking of the precipitate. It took approximately five seconds for the precipitate to reach the bottom of the shot glass.

Photographic Technique

A Nikon D300 12.3 mega-pixel digital SLR camera with a 105mm macro lens was for all images provided. The camera and lens combination provided the best resolution for the images the group wanted to capture. The camera was also chosen based on availability, functionality, and the requirements for the project. The field of view shown in the RAW file picture is approximately 25mm X 25mm. The distance from the table to the lens is roughly 30cm, but it is difficult to tell due to the macro lens used. While taking pictures of the apparatus, the distance provided enough of a safety zone to keep the camera equipment safe, as well as the operator. No flash was used during shooting. Using Adobe Photoshop's "EXIF" metadata option, the camera data is provided in the figure 3 below.

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[2] http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6V3J-44MSD8G-D-1&_cdi=5732&_user=918210&_orig=search&_coverDate=10%2F31%2F2001&_sk=999719992&view=c&wchp=dGLbVlW-zSkWz&md5=a54b79ff04faf53064487cbd7cdfc4d5&ie=/sdarticle.pdf

Figure 3: EXIF camera data

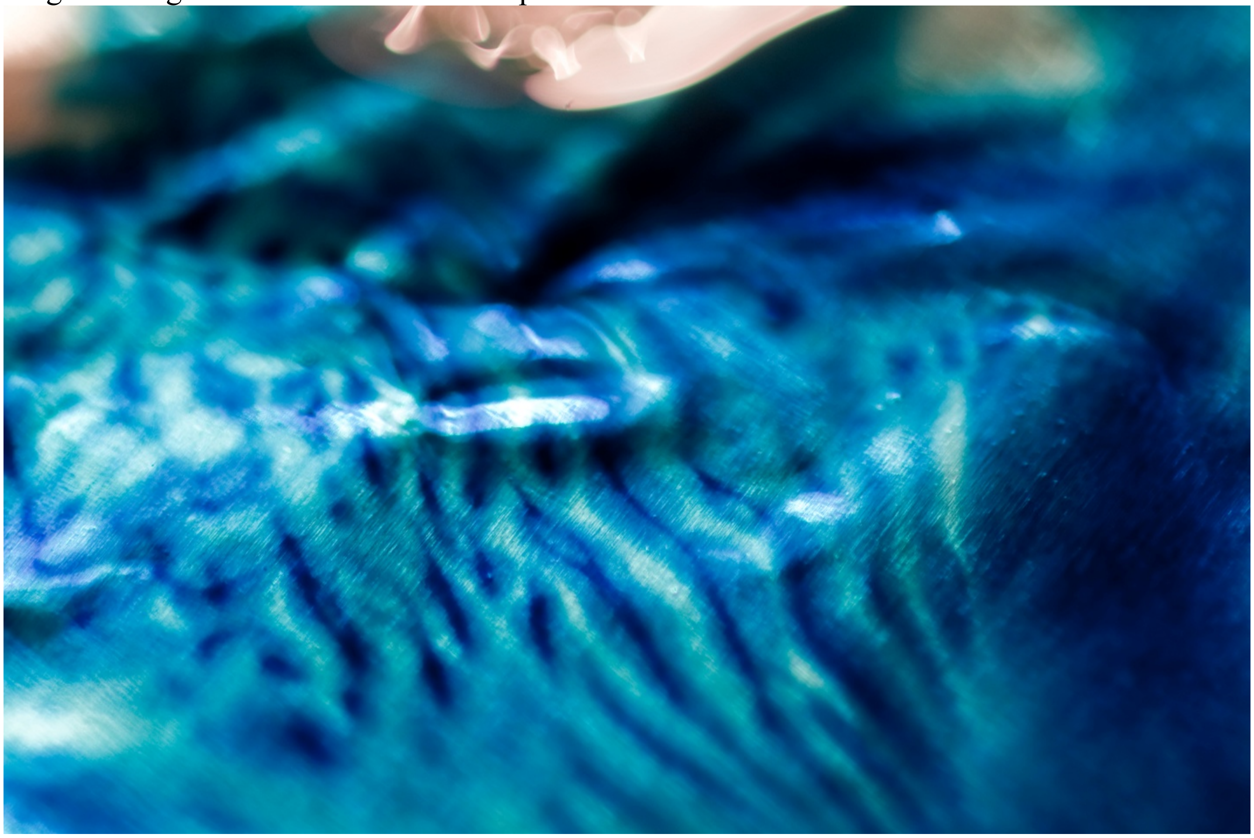
Make:	Nikon
Model:	D300
Date Time:	3/9/2009 22:00
Shutter Speed:	1/10 sec
Exposure Program:	Aperture priority
F-Stop:	f/13
Aperture Value:	f/13
Max Aperture Value:	f/4.7
ISO Speed Ratings:	320
Focal Length:	105 mm
Lens:	105.0 mm f/2.8
Flash :	Did not fire
	No Strobe return detection (0)
	Unknown flash mode (0)
	Flash function present
	No red-eye reduction
Metering Mode:	Pattern
Raw Picture Resolution:	4288 x 2848 pixels

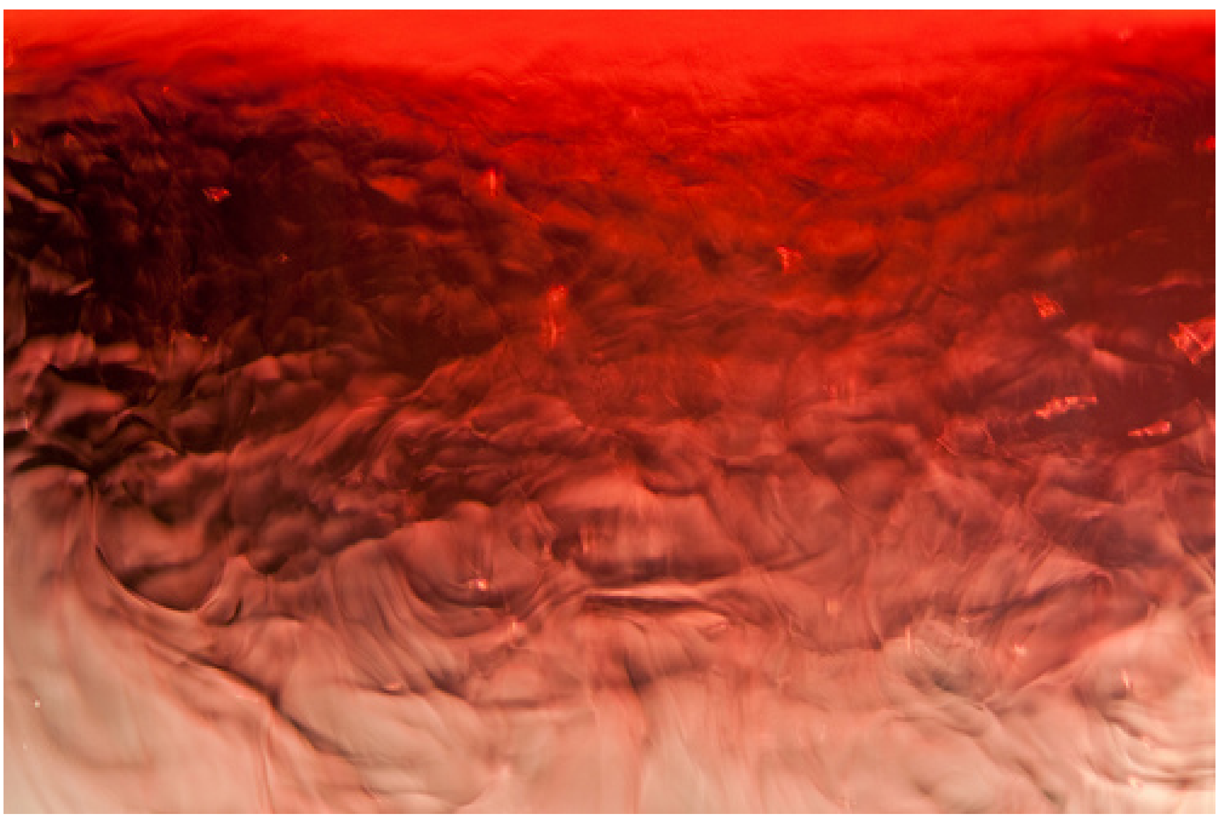
Revelations

The images reveal that interesting things happen when corn syrup and food coloring are combined with other household items. For the image in section 1.3, it seems as though the addition of baking soda and rice vinegar react not only with each other but with the corn syrup and food coloring as well. The reaction created a precipitate that was not seen previously. It would be interesting to recreate the experiment without the food coloring and see if the same phenomenon occurs. For the image in section 1.2, it seems that the addition of 200-proof ethanol and 3% hydrogen peroxide makes for much quicker diffusion. The aluminum foil helps reflect light in the image and highlights how the fluids flow.

The group attempted close to 120 photographs. All of the images were beautiful but the top three were selected for their interesting flow phenomenon.

Original images before Adobe Photoshop





References

1.1

[1]http://www.umaine.edu/marine/people/sites/pjumars/classes/SMS_481/SFLab.pdf

[2] http://en.wikipedia.org/wiki/Hydrogen_peroxide
http://www.h2o2.com/intro/properties/physical.html

[3] http://en.wikipedia.org/wiki/Ethanol

1.3

[1] Happel, J.& Brenner, H. (1981) *Low Reynolds Number Hydrodynamics*, Springer

[2] http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6V3J-44MSD8G-D-1&_cdi=5732&_user=918210&_orig=search&_coverDate=10%2F31%2F2001&_sk=999719992&view=c&wchp=dGLbVlW-zSkWz&md5=a54b79ff04faf53064487cbd7cdfc4d5&ie=/sdarticle.pdf