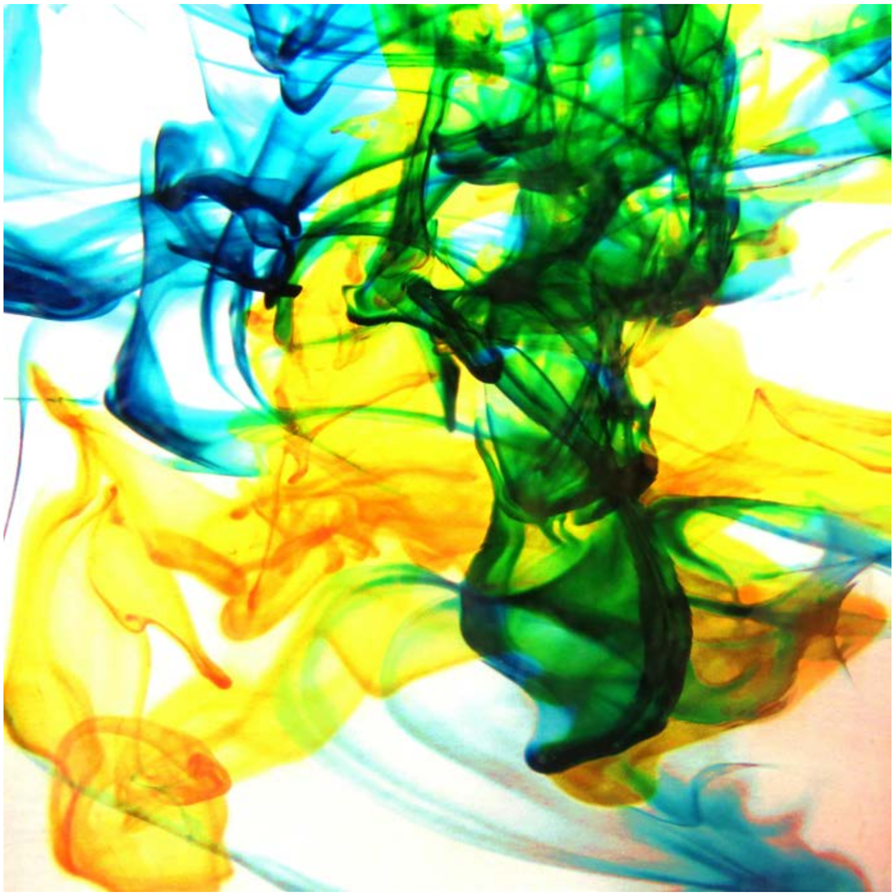
Get Wet Report



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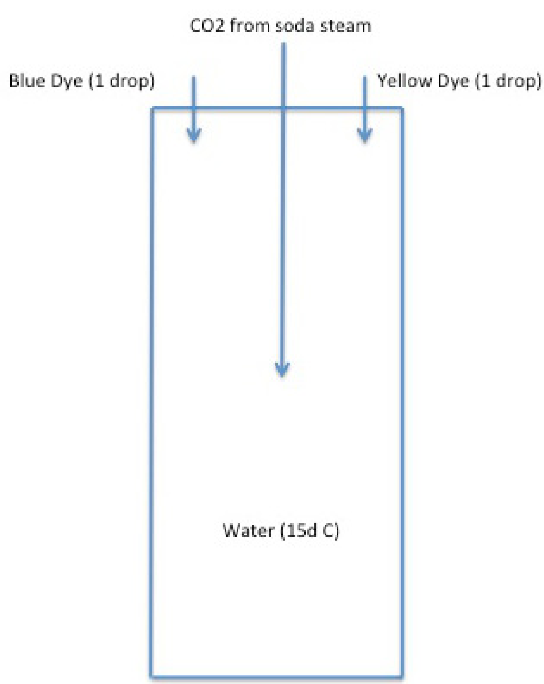
Introduction:

This is my first image taken for a project in this flow visualization class. There are a couple different phenomena that I attempted to achieve before capturing this image. All of my steps leading up to this image are important, including the failed processes that were attempted. I first wished to capture the turbulent flow of a Soda Stream injecting carbon dioxide into water in order to create carbonation. This flow was so incredibly fast that the phenomenon couldn't be captured in a professional manner. I still believed in the unique attributes that could be achieved by a flow with the addition of carbonation in water. I tried many different ways of capturing flows through carbonation and was able to achieve my image with the addition of food coloring. With this addition, I was able to achieve the phenomenon of colored dye mixing due to motion caused by the carbonation.

Apparatus:

The apparatus used to capture this image consists of a few things. First and foremost the water was carbonated with a machine called a Soda Stream. What this machine does is carbonates water in a bottle with a straw that is submerged in the water that shoots carbon dioxide into the water. The button to carbonate the water was pressed just lightly and was not held down. Through trial and error, the carbonated water was left for about an hour before the final image was produced. This caused the water to contain just a very small amount of carbon dioxide. The water was poured into a 16-ounce true pint glass. This pint glass has the dimensions of a top diameter of 3-¼ in. and a height of 5-7/8 in. With the water in the glass, an addition of two drops of dye were added to visualize the flow that was happening inside of the glass.



Fluid Flow:

One of the most important aspects of this image is the movement required to achieve the flow that is pictured. Just by dropping dye into a glass of water, you can achieve movement due to the forces of gravity on the dye itself. Food coloring is denser than water, which causes the solution to sink when placed within water. With a substance that is denser than its surrounding, gravity will have a force reaction pulling the substance to the bottom of the apparatus. In this image, I was able to use the force of gravity as well as the force from the carbon dioxide in the water to achieve a fair amount of movement causing my flow. The gravity for pulls the dye towards the bottom of the glass. On the other hand, the carbon dioxide is rising from the bottom pushing a small force upwards on the dye as well. This created a flow that had a greater force of gravity than upwards force but suspended the dye in place causing the two colors of dye to swirl around each other.

What is interesting in this photo is to look at the Reynolds number of the flow. To calculate the Reynolds number, the velocity of the fluid must first be calculated by comparing the densities of the fluids with the gravitational force being applied. The density of water can be assumed to be 999.7 (kg/m^3) [1] and the density of the dye used is 1032(kg/m^3) based on the main ingredient, propylene glycol [2]. The kinematic viscosity of the dye is equal to 48.6(mPas), which converts to 4.7(10^{-5}) (m^2/s).

The velocity of the fluid falling can be described as,

$$U_d = \frac{(\rho_d - \rho_w)R^2 g}{\rho_d v} \qquad Equation\ 1$$

Calculating the velocity,

$$U_d = \frac{(1032 - 999.7) * (.002^2) * (9.8)}{1032 * (4.7(10^{-5}))} = .025(\frac{m}{s})$$

$$Re = \frac{UD}{v}$$

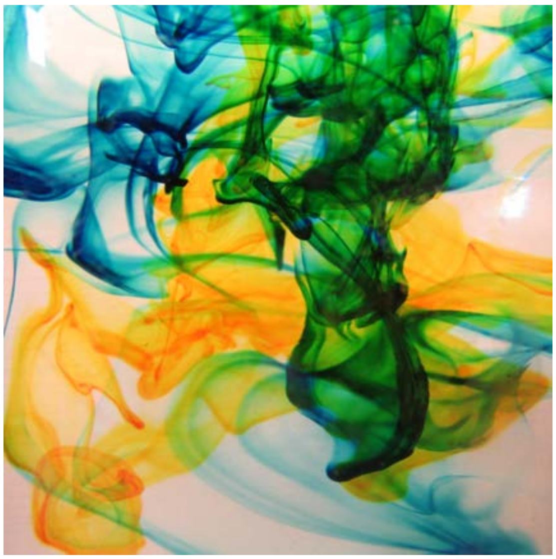
$$\frac{\left(.025\,\frac{m}{s}\right) * (.002\ m)}{4.7 * (10^{-5})(\frac{m^2}{s})} = 1.0638 \qquad Equation\ 2$$

You can tell by looking at Equation 2 that this is a laminar flow. This low Reynolds Number shows that the forces between the water and the dye are almost equal. This explains the floating phenomenon the two different dyes were able to achieve allowing light to pass through both colors creating the green "mixture". Part of this can be described as the umbrella effect that can happen to a denser fluid in water. Another aspect of this flow, and why the dyes did not completely umbrella, can be described by the addition of carbon dioxide into the water. When carbon dioxide is initially inserted into water, it is clear that the gas and liquid separate causing the form of bubbles. These bubbles are lighter than the water around them so they rise to the top. What is not as commonly understood is that some of the carbon dioxide is dissolved into the water [3]. In the case of this image, the bubbles had almost all dissipated because so much time had gone past before the dye was put into the water. The carbon dioxide had dissolved into the water changing the PH as well as the density. With a density closer to the density of the dye, there is less of a gravity force in the water suspending the dye in place for a small period of time when it enters the glass [4].

Photographic Technique:

The photography used to capture this image was fairly simple. Two drops of dye were placed at completely opposite sides of the water in the glass. A drop of blue dye was placed on the left side of the glass and a drop of yellow dye was placed on the right side of the glass. This enabled me to see the flow from both sides as they come together as well as distance themselves at different places in the flow. There was a light placed directly above the mouth of the glass shining directly down. This lamp was providing light from a 60 Watt bulb about 1 foot from the top of the glass. The ambient light in the room was very low but not pitch black. The flash on the camera was off, the only light sourced used was the lamp above the glass. The camera was placed almost against the side of the glass to take a horizontal shot. The backdrop behind the glass was a piece of white paper in front of a white wall.

The technique to capture this image is simple but it can be hard to achieve a perfect image. The distance from the lens of the camera to the flow was about an inch and a half. The lens was almost touching the glass and the flow was about in the center of the glass. This allowed the camera to focus on the flow within the glass rather than small details on the outside of the glass. The flow is about half the size of the apparatus in the image. This image was captured with a Canon SX520. The aperture was set to F5.6, the shutter speed was 1/60 of a second, and the ISO was set on 800. This allowed for the picture to be taken quickly but still in focus with the flow rather than other objects present. The aperture was chosen because of how close the lens was to the actual flow. The ISO setting allowed this effect to happen as well. With a lower ISO setting it was very easy to focus on what was exactly in front of the glass rather than the flow within the glass. There was not much post processing done to the image. The contrast was edited by using a curve and increasing the intensity of the white background. The size of the image stayed the same through the editing process. I intended to crop the image to focus in on once aspect of the flow but decided to keep the image the same size of 3456x3456 both before and after the processing phase.




Images Pre(left) and Post(right) processing

Conclusion:

I am very pleased by the way this image turned out. The way the green showed up from just a drop of blue and a drop of green dye is amazing. The green is not a mixing of the dye themselves but rather the light passing through one and then through another from the backside of the glass. This is an amazing feature that is shown in my image. One thing I do not like is how busy the image is. I would have liked to have a simpler flow between the two colors of dye but after many iterations, I could not get a flow as interesting as this. It is very busy but it is also very intricate. The two different colors of dye really allow the viewer to see the physics happening and how different they can be just millimeters apart due to the motion in the glass. To develop this further, I would like to do a similar experiment in a very large tank. I believe the introduction of carbon dioxide is an interesting source of motion and density change in the water. It makes the flow act very differently than if it was just water to begin with.

Appendix:

[1] http://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html
[2]http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_091b/0901b8038091b508.pdf?filepath=propyleneglycol/pdfs/noreg/117-01682.pdf&fromPage=GetDoc

[3] http://pubs.acs.org/doi/pdf/10.1021/ie50270a011
[4] http://www.sciencedirect.com/science/article/pii/0196890492900725