Fall 2015

Flow Visualization

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[TEAM IMAGE #2]

For this team image, our group wanted to capture something more artistic and utilize more colors. We were inspired by the works of Alberto Seveso [1]. I particularly like the way the colors wove together throughout the turbulent jet. I hoped to capture the elegant folds of the paint mixing. On top of having a certain artistic appeal, I also wanted to examine the shapes of turbulent jets. Each team member contributed to the success of the project. Joanna provided the paint and camera. She also contributed to how the lighting should be set up. Luke provided the tank and helped clean up after each experiment. Robert and myself helped mix and pour the paint.

This image was created by using Pro Art Liquid Tempura paints in both pink and white colors. This paint is naturally very thick and has a high viscosity. To allow the paint to flow through the water better, we mixed the paint with water until it could flow much more easily. We used multiple plastic cups to hold the paint solution in and then poured the cups together into a water tank. The paint was poured from about 2 inches above the surface of the water. The tank we used held a gallon of water. This smaller tank allowed for faster clean up. It is essential to clean the tank after each trial because the glass must be clean to get a clear image. The tank was positioned on a table with a black velvet background behind it. Lighting was difficult for the image because we used a very quick shutter speed. For our set up, we used four 250 Watt focusing floodlights positioned around the tank. The set up can be seen in Figure 1. Focusing the image was yet another challenge. To focus the camera we placed the paint bottles in the water. We could then make sure the text was in focus throughout the depth of the tank.

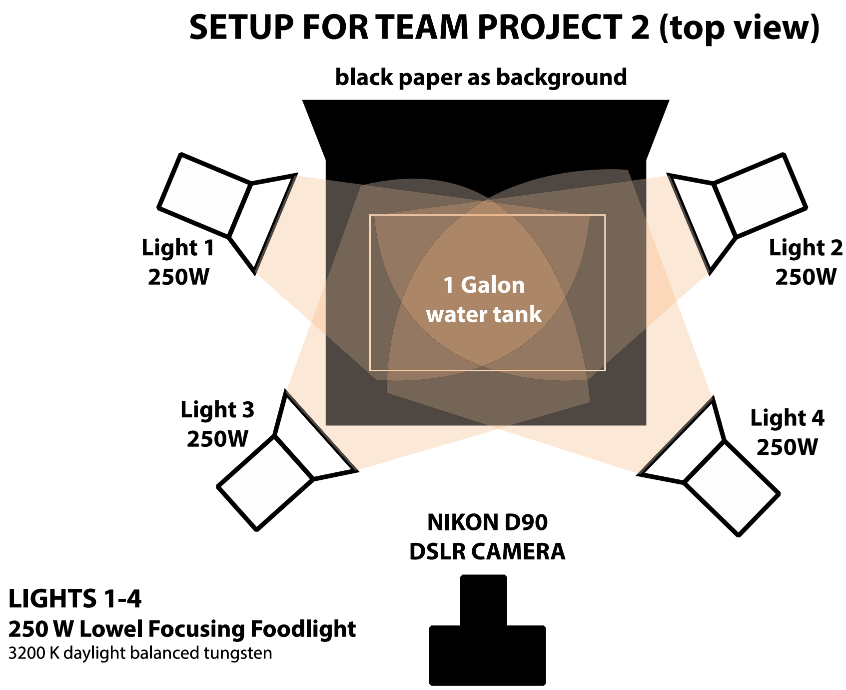

Figure 1: Set up using the Nikon D90 and 4 Floodlights [provided by Joanna Bugajska]

The table below shows important information regarding the how the image was captured. GIMP was used in post processing to crop and change the contrast. The color curves tool was used to darken the blacks and make a pure background color. Unfortunately, this affected the white paint color. It would be beneficial to alter the paint and background separately. The original image can be seen in Figure 2.

Camera	Nikon D90 DSLR Camera with 12 MP
Lens	Nikkor 18-105mm 1:3.5-5.6
ISO	400
Shutter Speed	1/1000 sec
F-Stop	F3.5
Contrast Setting	Normal
Original Size	4288x2848 pixels
Flash	No flash
Burst Mode	4 fps

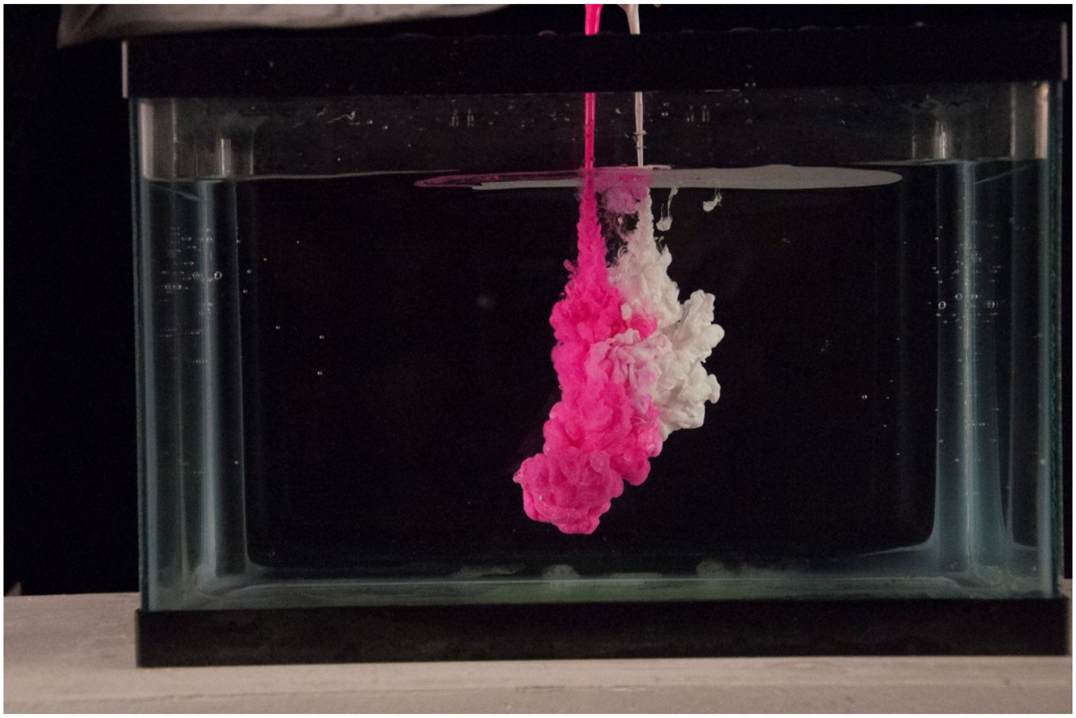

Figure 2: This is the unaltered original image captured

There is a lot of interesting physics surrounding turbulent jets. Jets are defined to be a boundary layer flow originating from a source of momentum. In this case, the source of momentum is us continuously pouring the paint out of the cup. These flows are considered turbulent because the turbulence level is much higher than the surrounding fluid. This turbulence is created by a velocity shear from the paint entering the water. It is important to note how each turbulent flow is very different depending on the fluids used, temperature and velocities. Despite being very different, most jets have an angle of 24 degrees from side to side. There is also a proportional relationship between the radius of the jet and the distance from the outlet. This relationship is approximately: $\tan(11.8) = \frac{1}{5}$ so $R(x) = \frac{1}{5}x$ where x is the distance from the injection point. Of course, this is not always true for this image because we have two jets mixing together. Figure 3 is a diagram of these relationships. Note how the stream of paint is not a single point but does have area. The point where the paint is poured is called the virtual source and this will act as our origin point [2]. From here we can calculate the distance to the water surface using the following equation:

$$x = \frac{5d}{2} = \frac{5(0.02m)}{2} = 5cm$$

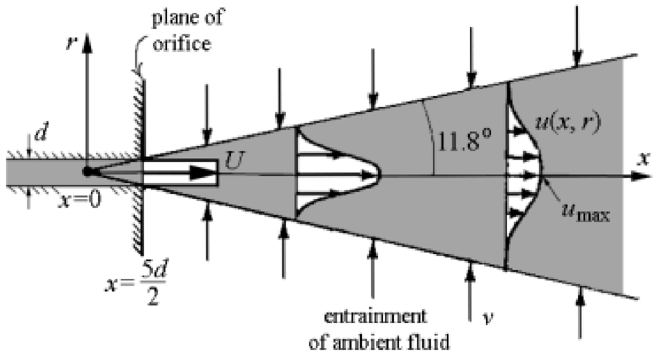

Figure 3: Schematic of a turbulent jet and the velocity profiles at different distances

We can also calculate the Reynolds number which shows the relationship between momentum and viscous forces [3]. Since we calculated a large Reynolds number, we can conclude that the jet seen is in fact turbulent.

$$Re = \frac{uL}{v} = \frac{\left(\frac{5m}{s}\right)(0.1m)}{1.5e - 6} = 3.3e5$$

This image captures the physics of how turbulent mixing occurs in fluids. I especially like the visual effects of this mixing because it creates very beautiful folds in the paint. I also like the colors used because the pink and white stand out from the black background. If I was to do this project again, I would have a lower ISO so the image would have less noise. I would also try disturbing the water before the paint was added.

References

[1] (n.d.). Retrieved November 25, 2015, from http://www.burdu976.com/phs/

[2] Turbulent Jets. (n.d.). Retrieved November 25, 2015, from https://engineering.dartmouth.edu/~d30345d/books/EFM/chap9.pdf

[3] Reynolds Number. (n.d.). Retrieved November 25, 2015, from https://en.wikipedia.org/wiki/Reynolds_number