Project 1: Get Wet

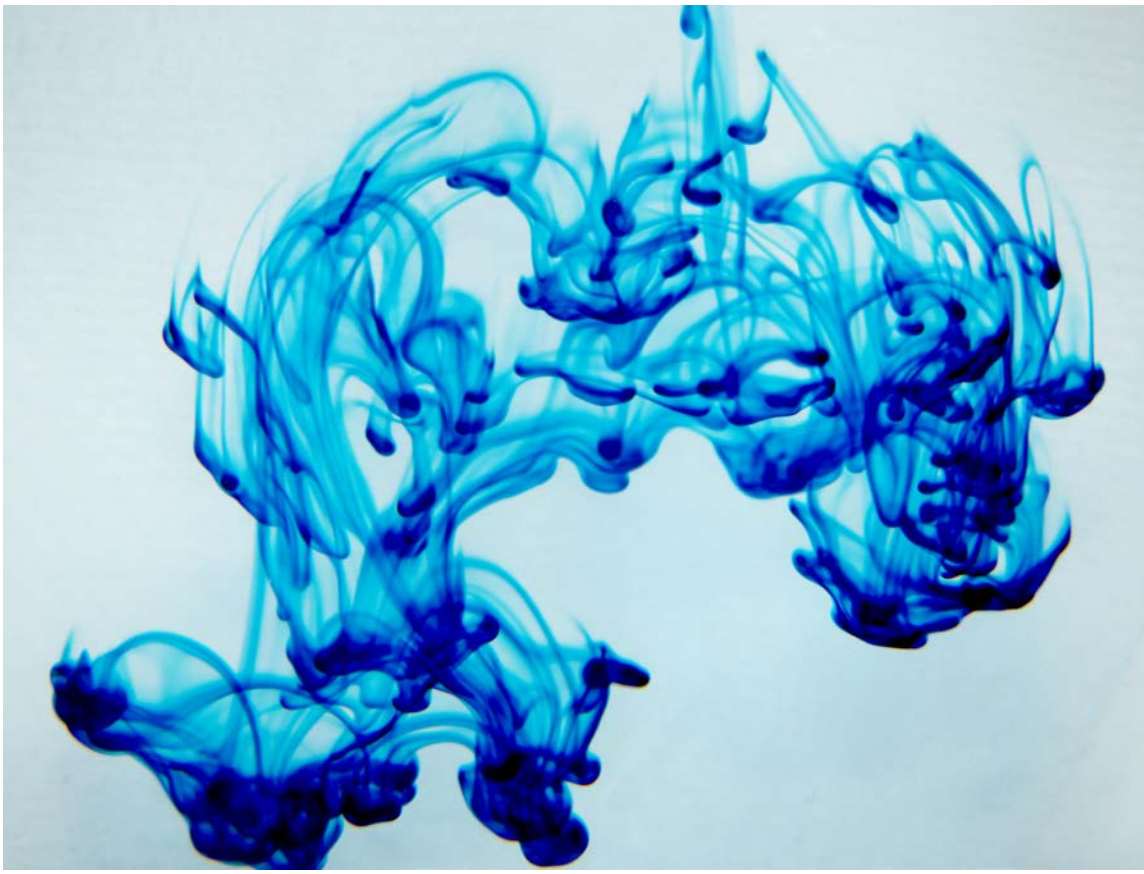
Figure 1: Get Wet final image.

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Introduction

The purpose of MCEN 4151 is to experiment and examine fluid flow through use of captivating photos. For the initial project, the students were asked to “get our feet wet” by making a photo that demonstrates a phenomena and is a good picture. Essentially, there were no limits on what we could produce.

The students were encouraged to look at past Flow Visualization galleries to help get an idea of what we were capable of capturing. The dye-in-water pictures were especially fascinating because of the mix of simplicity in the setup and complexity within the fluid.

Fluid Physics

The fluid shown in the image displays the Rayleigh-Taylor instability. This occurs when there is an interface between two fluids of different densities.[1] In this case, the heavy water-based food dye is sinking in the water. The instability is highly governed by the Reynolds Number, abbreviated Re. When the two fluids are mixing, and Re>1, the fluid will maintain a spherical shape while dropping through the lighter fluid. When 1<Re<100, the drop will create a torus while sinking. When Re exceeds 100, the instability begins.[2] For this experiment, the following calculation was made:

$$Re = \frac{u_d R}{v} = \frac{\left(1\,\frac{m}{s}\right)(.0015\,m)}{1.004\,x\,\frac{10^{-6}m^2}{s}} \approx 1500$$

This relatively high Re translates to very unstable mixing at the surface of the water. The dye was subject to the bag break-up. The bag break-up consists of the spherical drop becoming a torus and then creating a bag-like shape,[3] as seen in the final photo. This bag like shape is due to the high Re and the fast mixing that is occurring behind the front.

There was also some movement of the water inside the tank before the food dye was dropped. This accounts for the large separation in the left and right side of the plume.

Experimental Setup

All of the experiments used a camera on a tripod that was facing the broad side of a small aquarium. A small sheet of toilet paper was hanging inside the tank to reduce the flash glare. The white poster and t-shirt were also used to diffuse glare. The following image shows the arrangement.

Figure 2: Experimental setup.

The initial experiment was set up to examine density-driven fluid flow. This was accomplished by dropping a shot glass filled with dyed vegetable oil into an aquarium filled with cool water. The oil has a lower density, so when the shot glass is dropped in, the glass will sink to the bottom and then the fluid will rise. The following pictures were captured.

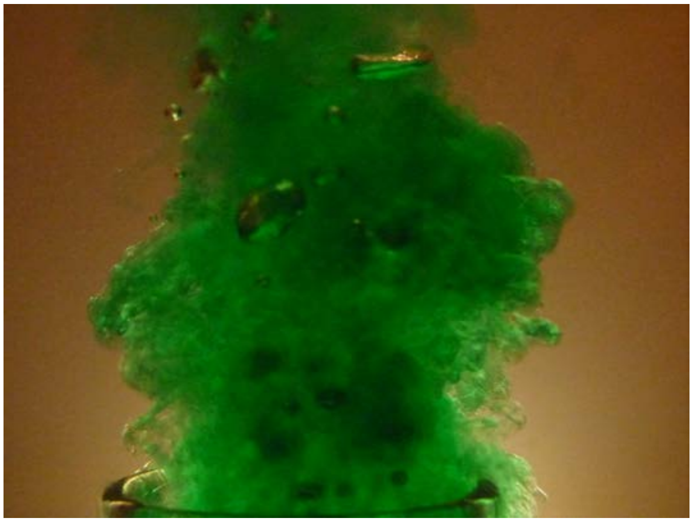

Figure 3: Dyed vegetable oil dropped in water. This image was captured without the camera flash but used a camping light behind the tank. Also, no toilet paper was in the tank.

Figure 4: Dyed vegetable oil dropped in water. This image was captured with flash and no toilet paper in the tank.

These images were interesting, but they only proved that there was more to capture in terms of sharpness. The next step was to abandon the shot glass idea and begin working with simple dyes.

The blue dye is best to use because it displays a better contrast against a white background than yellow or green. The water in the tank was kept at a cool temperature, although not cold enough to create condensation on the outside of the tank. The dye was kept at room temperature. While the operator had the camera focused and ready to capture, one drop of blue dye was dropped from 1 cm above the surface of the water.

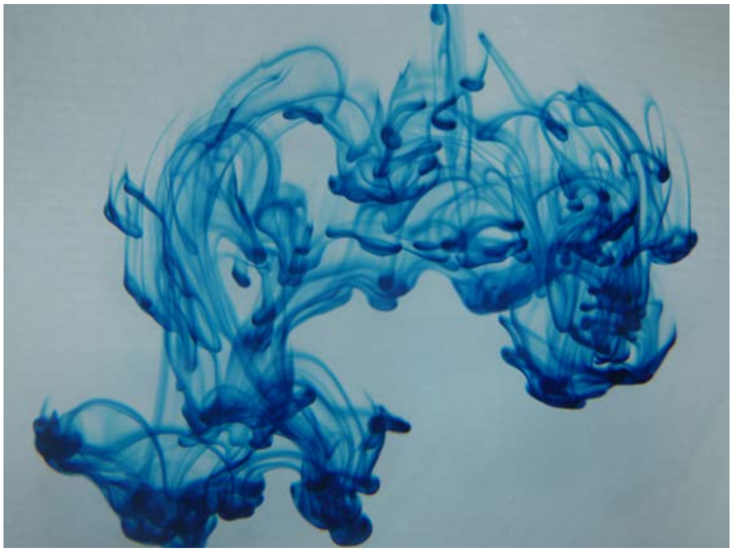

Figure 5: Original unedited photograph.

Image Capture

The photo was taken with a Panasonic Lumix DMC FZ70 16.1 MP camera. Due to the high intensity light from the camera flash, the ISO was set to 100. The aperture was set to 5.6. In addition to being zoomed in 2x, a 4x close-up lens was attached to the front of the camera. The camera was approximately 5 cm away from the tank. And the shutter speed was set to 1/2000.

The camera came with a recommended developer program called SILKYPIX 4.3 Developer Studio. This program was used to increase the sharpness around the edges of the dye and increase the contrast to reduce the background to white. This image was then sent to Adobe Photoshop to be color reversed.

Figure 6: Color reversal of the final image.

Conclusion

The student was effectively able to capture this natural phenomenon by creating an environment that allowed for the mixing of two fluids to be observed. The two fluids interacted in a way that made for a fascinating photo. This phenomenon deserves to be photographed and studied. Perhaps using two more dense fluids and a bigger tank would make a better photo with a slower mixing rate. Also, finding a way to drop the dye into the water with the lowest velocity possible would create a nice subject.

References

1.
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https://en.wikipedia.org/wiki/Rayleigh-Taylor_instability

2.
Bosse, Thorsten. Kleiser, Leonhard. Hartel, Carlos. "Numerical simulation of finite Reynolds number suspension drops settling under gravity." Physics of Fluids 17, 037101 (2005).

3.
Rimbert, N. Doisneau, F. Laurent, F. Kah, D. Massot, M. "Two-layer mesoscopic modeling of bag break-up in turbulent secondary atomization." Center of Turbulence Research. Proceedings of the Summer Program 2012.