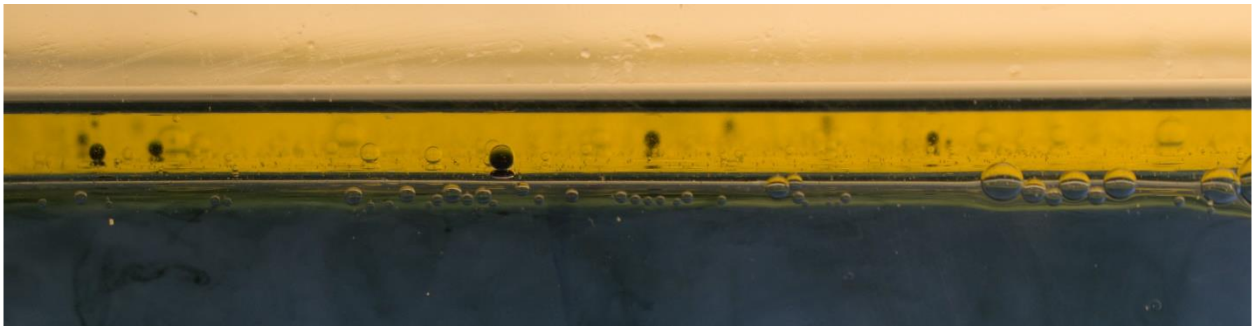

Team Third Report

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MCEN 5151: Flow Visualization

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I. Overview

This image was taken for the third team assignment for MCEN 5151: Flow Visualization. For this assignment, my team initially wanted to photograph the shear boundary layer between oil and water created by a Styrofoam plate moving on the surface with a constant velocity. However, this phenomenon was much more difficult to photograph than we anticipated. After multiple attempts, we decided to switch courses and see what other types of fluids phenomenon we could create with our set up including oil, water, and food coloring. The final picture I chose to submit for this assignment features small bubbles of water-soluble food dye suspended in the layer of oil.

II. Experimental Set Up

For this assignment, my team used a 15-gallon fishtank with about 6 gallons of water and a two-inch layer of canola oil. To set up the fishtank, we placed the fishtank box behind it and covered both the box and the table with velvet fabric. This ensured that we had a solid background for our images and reduced reflections. After this, we placed white paper behind the section of the fishtank where our camera was focused. This brightened the image and helped make the details of the flow visible. A schematic of the set up is shown below in Figure 1, and a photograph of the setup is shown below in Figure 2.

To add the food dye droplets, we waited until the oil and water layers were settled. From here, we used a toothpick covered in Wilton food dye to carefully insert droplets of food dye into the oil layer.

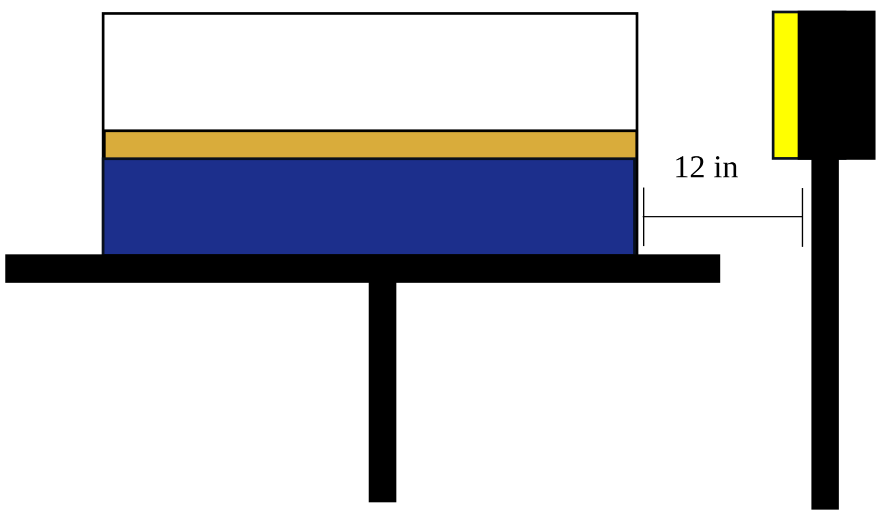

Figure 1: Schematic of experimental set up.

Figure 2: Photograph of experimental set-up.

III. Visualization and Photographic Techniques

This photograph was taken in the small presentation room off of the lower basement level of the ITLL. We shut off all lights in this room to ensure that the only light source was our artificial light source. To prevent reflections on the surface of the fishtank and the fluid, we angled the light source towards the white board at the back of the room to create a more indirect source of light. The light source used a combination of white and yellow light. The position of the light source with respect to the fishtank is shown above in Figure 2. The photograph was taken from the front of the fishtank, with the camera about 12 inches away from the surface of the tank. The field of view of the image is about six inches.

The spatial resolution of this image has an order of one and the image is considered time resolved, which indicates that it captures a momentary instance of the fluid flow.

This image was captured using a Nikon D5500 DSLR camera with a Nikon AF-P Nikkor 18-55 mm lens set to a focal length of 50 mm. The exposure was set to 1/50 s, the aperture to f/7.1, and the ISO to 250. The original image has dimensions of 6016 x 4016 pixels, and the edited image has dimensions of 3000 x 774 pixels.

When editing this image, I significantly cropped it to better focus on the oil droplets suspended in the oil layer. Additionally, I increased the global vibrance, increased the white relative exposure, and decreased the black relative exposure of the image. This made some of the details of the water more visible.

Figure 3: Original unedited image.

IV. Fluid Dynamics

The Eötvös number (Eo) is a dimensionless number that characterizes the gravitational forces vs the surface tension forces of a fluid. This number can be used to characterize the shape of a bubble moving in the surrounding fluid. The formula for the Eötvös number is shown below in equation 1, where Δp is the difference in density between the two phases, g is gravitational acceleration, L is the characteristic length, which in this case is the radii of the drop, and γ is the surface tension [1].

$$Eo = \frac{\Delta p g L^2}{\gamma} \quad (1)$$

Table 1: Values for Eötvös number calculation.

Variable	Value	Value (SI)	Source
Δp	1,217.3 kg/m^3 - 904 kg/m^3	313.3 kg/m^3	[2], [3]
g	9.81 m/s^2	9.81 m/s^2	Previous classes
L	0.2 cm	0.002 m	Estimated from video
γ	0.0342 N/m	N/m	[4]

Using the values shown above in Table 1, I calculated an Eötvös number of 0.3594. As the Eötvös number is less than one, that means that the surface tension forces dominate. This leads to the bubbles shown in the image, where they are suspended within the oil rather than falling through to the water layer below.

V. Image Conclusions

Overall, I am happy with this image. While I am disappointed that my team's original idea did not work out, I think we still managed to create an image that is very visually interesting and displays some interesting fluids phenomenon. I really like the contrast in color between the dark color of the food dye droplets and the yellow of the oil. For future experiments, I would try and capture an image earlier in the experimental process, where the layer of water below the food dye had not yet been colored. I think that being able to capture the diffusion of the food dye in the water, along with the drops in the oil, would have been very interesting.

VI. References

[1] Chatterjee, J., (2002). Critical Eotvos numbers for buoyancy-induced oil drop detachment based on shape analysis, Advances in Colloid and Interface Science, https://doi.org/10.1016/S0001-8686(01)00098-7.

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[3] Jenab, E., Temelli, F., (2012), Density and volumetric expansion of carbon dioxide-expanded canola oil and its blend with fully-hydrogenated canola oil. The Journal of Supercritical Fluids. https://doi.org/10.1016/j.supflu.2012.03.018.

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