Faisal Alismail
Team Third Report
MCEN 4151 Flow Visualization
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Oil Bubbles in Water

The team third assignment is created to allow students to work together to develop an experiment that demonstrates a fluid phenomenon and shows an artistic side. Being in a group of five members allows us to build our own setup, perform and test the experiment, and record the outcome using a video or a picture. This time our team performed an experiment called Oil Bubbles in Water. The addition of oil to a glass of water resulted in bubbles formed inside the water. The quantity and the shape of the bubbles allowed us to take multiple pictures that demonstrated the fluid phenomenon behind it.

Working with canola oil and water means that we have different densities to account for. Water has a density of $1.00\,\frac{g}{cm^3}$, and canola oil of $0.92\,\frac{g}{cm^3}$ [1]. Since the oil has a density that is less than water, both fluids will not mix, and the oil will flow to the top and form its own layer. Another reason why these two do not mix is that water is known as a polar molecule, while the oil is known as a nonpolar molecule [2]. Therefore, the water molecule has a negative charge on the bottom side and a positive charge on the top side. On the other hand, the oil molecule does not have opposite charges at both ends [2]. Now in our case, what we did was pouring some oil into the water, which led to bubbles forming and rising to the surface of the water. The reason behind that was when we forced the oil to flow into the water, the oil could not mix with the water, so it formed bubbles to make it travel back to the surface of the water. One thing I noticed when the oil entered the water was how fast the bubbles traveled to the surface. To calculate the velocity of the bubbles, we could use the following equation [3]:

$$v = \sqrt{\frac{8rg\left(\rho_l - \rho_g\right)}{3\rho_l C_d}} \tag{1}$$

where v is the velocity, r is the radius of the bubbles, g is the gravitational constant, p_l is the density of the water, p_g is the density of the oil, and C_d is the drag coefficient of the water. In order to solve for the velocity, a few assumptions must be made first. The radius of the bubbles is assumed to be constant for all bubbles and it is 0.006 m. The coefficient of drag is 1.8. Therefore, solving the equation we get:

$$v = \sqrt{\frac{8(0.006m)\left(9.81\left(\frac{m}{s^2}\right)\right)\left(1000\left(\frac{kg}{m^3}\right) - 920\left(\frac{kg}{m^3}\right)\right)}{3\left(1000\left(\frac{kg}{m^3}\right)\right)(1.8)}} = 0.0835\left(\frac{\text{m}}{\text{s}}\right) \quad (2)$$

which is a reasonable value for the velocity, considering the size of the glass.

Moving on to how we set this experiment up, we decided to work in one of the ITLL classrooms, using one of the tables as our base. We had a small glass 2.5 inches wide by 4.5 inches tall, a plastic dropper, canola oil, a black cotton sheet, two iPhones used as a flashlight, a tripod, and a Sony camera. Now, we started by filling up the glass with water and let it settle, then we placed the black sheet behind the glass to block the surrounding environment and create a black workspace. Then we placed two iPhones beneath the glass facing up with the flashlight on to provide the lightning we needed. Meanwhile, we set up the tripod and placed the camera in front of the glass and about 10 inches away. Once the settings were adjusted and the camera was focused on the glass, we poured some oil into the water using the plastic dropper. Having the dropper let us control the amount of oil that goes into the water. Once the oil was inside, bubbles started to form, and we captured multiple images until the bubbles settled on the surface of the water. The schematic below shows our experimental setup.

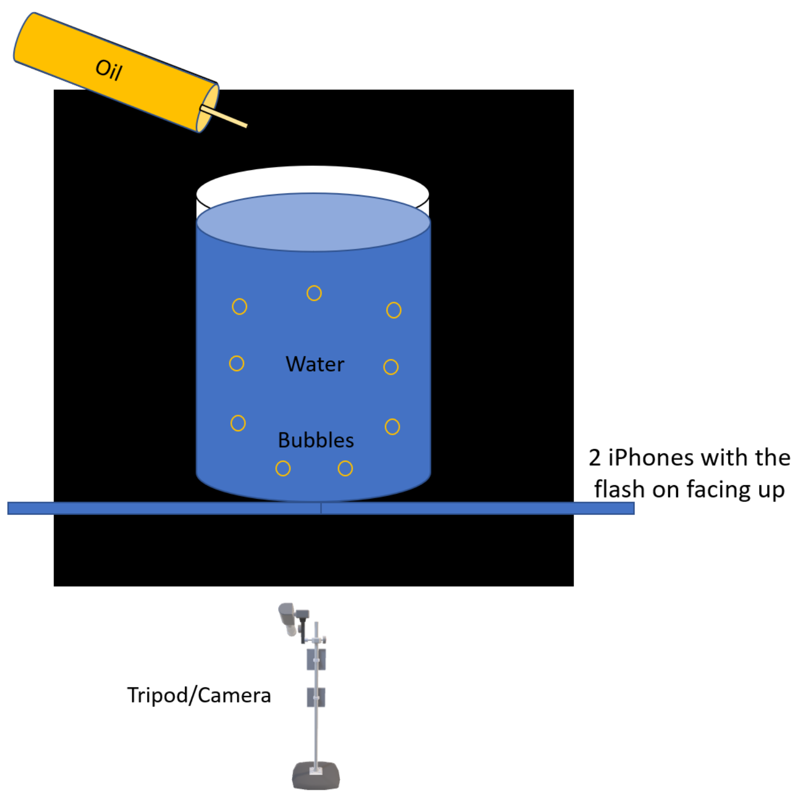

Figure 1. Schematic of our experimental setup.

The camera used to capture this image was the Sony ILCE-7RM2. The lens attached to the camera was FE 16-35 mm type. Now the camera was set to the following settings: an aperture of F/4.0, an exposure of 1/4000. The ISO was 102400. The focal length was 24 mm, and a resolution of 8000 width, and 5320 height. The field of view was about 6 by 6 inches. Now to post-process this image, I used an application called Darktable. Under the exposure settings, I adjusted the black level correction to 0.0172, and the exposure to -0.10EV. This allowed me to eliminate the surrounding environment and focus on the glass. Moreover, under the white balance settings, I changed the temperature from 3953K to 8716K, which changed the color of this image from black and white to a goldish color.

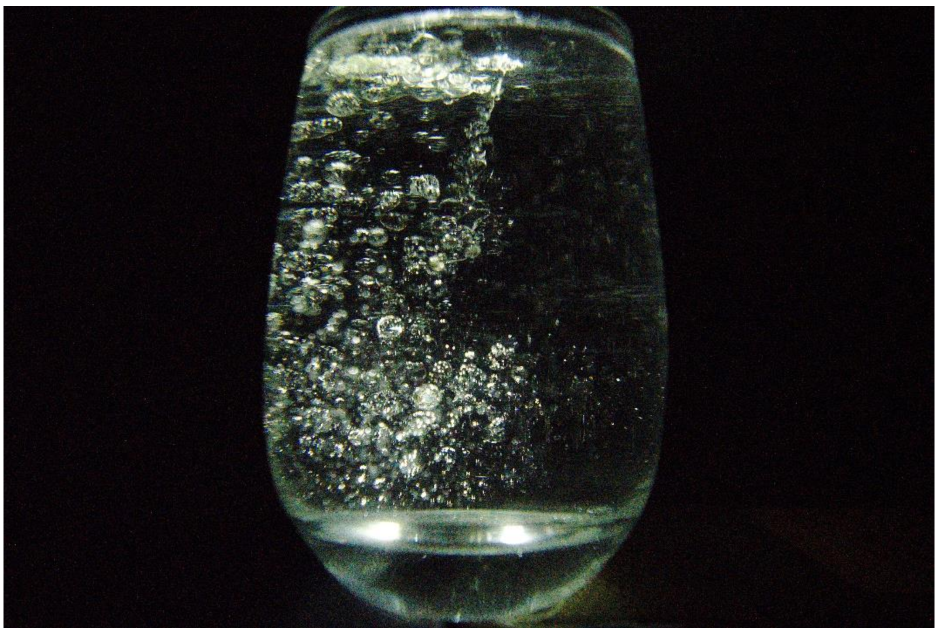

Figure 2. The original image extracted from the camera.

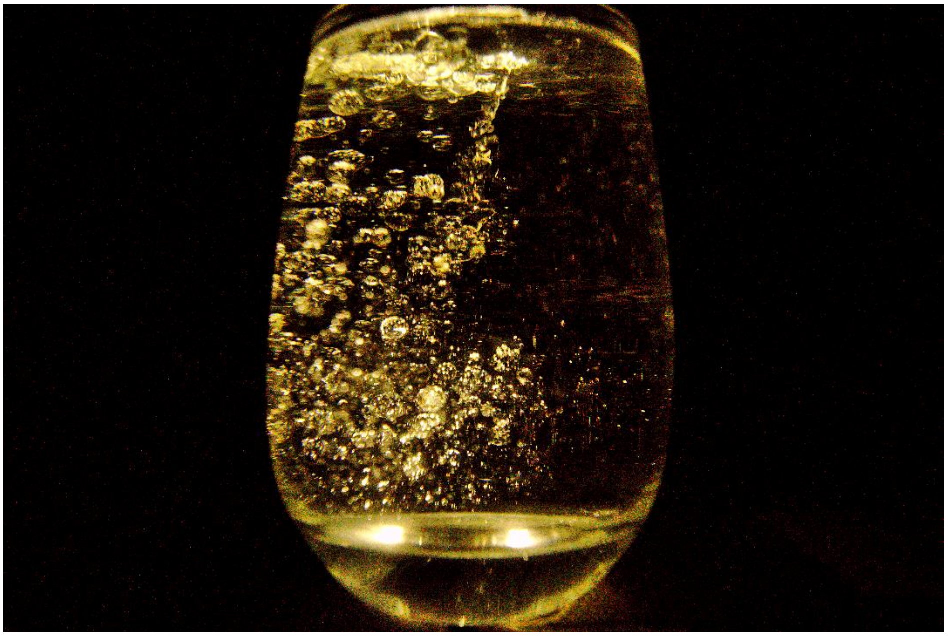

Figure 3. The edited version of the image.

In conclusion, the image shows some cool spherical bubbles formed inside the water. The image clearly shows the intended phenomenon and fulfills its purpose. I like how we were able to make perfect spherical bubbles and capture them as well. To improve this experiment, we could use a high-speed camera that would clearly capture the bubbles on the bottom and the edges of the glass instead of just the middle bubbles.

References

[1] Amazing 9 Layer Density Tower - SICK Science!: Experiments: Steve Spangler Science. (n.d.). Retrieved from https://www.stevespanglerscience.com/lab/experiments/density-tower-magic-with-science/
[2] Bubbling Blob - Lava Lamp: Experiments: Steve Spangler Science. (n.d.). Retrieved from https://www.stevespanglerscience.com/lab/experiments/bubbling-lava-lamp/.
[3] M.Y. Shi et al 2017 IOP Conf. Ser.: Mater. Sci. Eng. 231 012093. Retrieved from https://iopscience.iop.org/article/10.1088/1757-899X/231/1/012093/pdf