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MCEN 4228 – Flow Visualization
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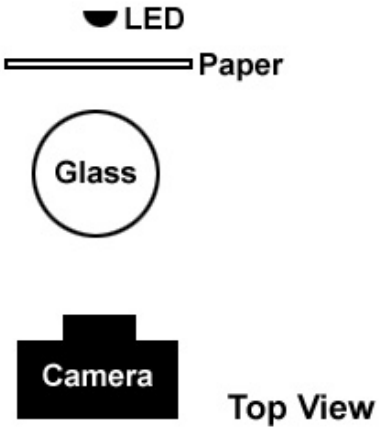
Team Project 3

The purpose of this image is to show several types of fluid physics at the same time and how several very different fluids interact with each other. This image contains three different fluids: water (liquid), oil (liquid), and carbon dioxide (gas). The oil floats on the water illustrating the affects of two fluids with different densities. The carbon dioxide gas flows through both of these fluids and shows how bubbles of carbon dioxide gas behave differently in each. The actual flow here is not very fast and appears very laminar. This image came to be only through several hours of experimentation with dozens of fluids. Ultimately, this seemed to be the best approach. I experimented with a few different types of glasses for this specific experiment (including a shot glass, a martini glass, and a coffee pot), but ended up using a pint glass because it was large and revealed the most amount of detail.

The set-up for this image required pouring a 1.75 inch tall layer of canola oil on top of a 1.75 inch tall layer of water in a 5.5 inch tall glass. This was allowed to settle, and the oil formed a layer floating on the water with a distinct boundary layer between the two. This was because the oil has a lower density than the water. An LED flashlight was held behind and below the glass, and the light was passed through a piece of paper that leaned against the back of the glass. The paper acted as a filter to prevent the LED light from causing reflections on the glass.

The set-up looked like this.



After everything was set up, an Alka Seltzer tablet was dropped into the glass.

The image shows the flow of carbon dioxide gas through two different fluids—water and canola oil. Carbon dioxide gas is released by the Alka Seltzer tablet that was dropped into the glass. The gas flows in very small bubbles upward due to buoyant forces. The small bubbles collect into a large bubble in the oil because it is a higher viscosity fluid which produces a bubble with high surface tension. The bubble stays intact until the buoyant force of the gas within the bubble is large enough to cause a break in the bubble. Small bubbles then break from the larger bubble and float to the top where they are released to the atmosphere.

The small carbon dioxide bubbles flow through the water at about 9 inches/second in a stream with an approximate diameter of .75 inches and about 1.75 inches in length (from the tablet to the boundary layer of the water and oil). The highest Reynolds number of this flow is at the boundary layer and is calculated by the following:

$Re_{CO2\_in\_oil}$ = (V)(D)/(kinematic viscosity of CO_2) , D = .2 in = 0.0167 ft,

V = 9 in/sec = .75 ft/sec, kinematic viscosity (CO_2) = 8.65 X 10^{-5} ft^2/sec

$Re_{CO2\_in\_oil}$ = (0.0625 ft)(.75 ft/sec)/(8.65 X 10^{-5} ft^2/sec) = 541.9

This is well within the laminar realm. The small carbon dioxide bubbles flowing out of the bubble in the oil flow at about 4.5 inches/second in a stream with an approximate diameter of .2 inches and about 1.2 inches in length (from the top of the bubble in the oil to the top of the oil layer). The highest Reynolds number of this flow is at the boundary layer and is calculated by the following:

$Re_{CO2\_in\_oil}$ = (V)(D)/(kinematic viscosity of CO_2) , D = .2 in = 0.0167 ft,

V = 4.5 in/sec = .375 ft/sec, kinematic viscosity (CO_2) = 8.65 X 10^{-5} ft^2/sec

$Re_{CO2\_in\_oil}$ = (0.0625 ft)(.375 ft/sec)/(8.65 X 10^{-5} ft^2/sec) = 271.0

This is also well within the laminar range.

The boundary layer between the oil and the water was made clearly visible by selecting specific fluids. The canola oil naturally has a yellow hue to it, making it distinguishable from the clear water. The Alka Seltzer was of the Orange Zest variety and released an orange dye in the water as the carbon dioxide was being released. This furthered the contrast between the water and oil layers. To illuminate the glass, an LED flashlight was placed behind and below the glass. A white piece of paper was put in front of the light so as to filter the light and prevent the glass from reflecting it.

The field of view is about 7 inches tall and 5 inches wide. The height of the glass is about 5.5 inches. The camera was placed on a book about 12 inches from the glass. The focal length of the lens was 10.7 mm. The camera used was a Kodak DX7630 Zoom, a digital camera. The original image width was 2856 pixels and the height was 2142 pixels. The ISO setting was 400, and the exposure time was 1/10 of a second. Because the image was shot at fairly low light, the exposure time could not be extremely fast. The aperture was set to 3.5 to allow enough light in to view the all of the details in

the image while still maintaining a significant amount of contrast. Photoshop was used a good bit, but not in a way that it affected the important information in the image. The image was cropped to remove some of the background that was illuminated by the LED light. Since the LED light was sent through a paper filter, the paper was clearly visible. The paper was removed along with the rest of the visible background that could not be cropped out. The glass that I used was a Guinness brand glass and had the logo on it. Although I turned the glass so as to hide most of the logo, several letters were still visible. These were stamped over using the stamp tool in Photoshop. The level of contrast in the original image was not as high as it needed to be, so I adjusted it as well as the brightness to reveal the full spectrum of detail in the image.

The image illustrates laminar flow, surface tension of bubbles, and two fluids of different densities floating on each other. Carbon dioxide gas is released by the Alka Seltzer tablet and flows through the water to the boundary layer of the oil. The gas then forms a large bubble in the oil and eventually develops a break through which the carbon dioxide is released through the oil and then, ultimately, to atmosphere. I experimented with many different things while attempting to get an image for this project. Many different fluids and flow visualization methods were used. Ultimately, this was the most aesthetically pleasing image and revealed a wide spectrum of physics principles. I like everything about this image except that it is slightly out of focus. My camera has an auto-focus and usually just cannot seem to focus specifically on my subjects. I think this image has even more detail to be revealed and would look much better if taken with a better camera. Otherwise, I think the image that was produced is a good one.