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MCEN 4151: Flow Visualization

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This image was taken for the second group project in the Flow Visualization course (MCEN 4151) at the University of Colorado in Boulder. It shows the motion of vegetable oil through water. The primary properties demonstrated in this image include density, surface tension, and cohesion.

For this image, an acrylic box of dimensions 7"x22"x10" was constructed by a team consisting of Brittany Feddersen, Davis Fogerty, Jaewon Kim, Lisa Logel, and Justin Simmons. The box was constructed in a combination of the Durning lab and the ITLL at the University of Colorado at Boulder. The seams were sealed with a liquid acrylic adhesive, and have not had a problem with leaking over 2 weeks later with no signs of impending leaking. The box was filled about half way with water which had been dyed blue, and the rest was filled with vegetable oil which has a naturally yellow color. This image is a direct effect of the hydrophobicity of the acrylic. When the box was tipped over, the oil had a tendency to stick to the acrylic, but the buoyancy force of the oil opposed this cohesion force. The bubble of oil was approximately 1 inch in diameter, and 1.5 inches tall.

Oil has an approximate density of 927 kg/m^3, while water has an approximate density of 999 kg/m^3. This gives a buoyant force of about 9.4 N if the bubble is modeled as a cylinder according to the equation:

$$B = \frac{2g\rho_o V \rho_w V}{\rho_o V + \rho_w V} = \frac{2\left(9.8\frac{m}{s^2}\right)(927\ kg/m^3)(0.001\ m^3)(999\ \ kg/m^3)(0.001\ m^3)}{(927\ \ kg/m^3)(0.001\ m^3) + (999\ \ kg/m^3)(0.001\ m^3)}$$

This would result in an upward acceleration of about 0.366 m/s. As the buoyant force combated the cohesion force, the bubble would break apart, much like what is seen with water dripping off of a faucet through air.

The bubble of oil can be seen due to the differences in the index of refraction between the oil and the water. This makes it so that the edges of the boundary between the oil and water can be clearly seen. Due to the stronger coloring in the water, the picture is predominantly blue; however there is a light green tinge in the bubble where the yellow of the oil contributes to the coloring. The flash was on when the picture was taken which accentuates the smooth surface through reflections. Some smaller bubbles can be seen within of the larger bubble, this is due to small amounts of water getting trapped in the oil. The surface tension in these cases is too great for the buoyancy forces to overcome. Additionally, there are many medium sized bubbles at the base of the larger bubble. These bubbles gather there because it is right next to the acrylic, which is (as previously stated) hydrophobic, so it is an ideal place for the oil to gather.

The picture was taken using a Canon EOS Rebel T2i. The f-stop was f/4, and an exposure time of 1/60 sec., an ISO of 400, and a focal length of 100mm was used. The original image is included below (Figure 1). Gimp was used to slightly alter the picture. The contrast was increased using the curves tool. Additionally, some glare was removed using the clone tool. Neither of these alterations significantly alters the physics of the phenomenon.

I like the way this image turned out. A lot of the pictures from our group looked really messy due to an overabundance of bubbles, but I really like the simplicity of the single bubble. I think that increasing the contrast really brought out the colors and made the blue look a lot nicer. I like how sharp the edge of

the bubble turned out, especially in the upper right part. And the background is really mellow without being completely uniform. I would have liked if the depth of field would have been just a little better so that the whole surface of the bubble would have been sharper. Overall though, I think the image is aesthetically pleasing while still properly displaying the physics of the situation. Also, it does totally look like the blob from Monsters Vs Aliens (Figure 2)

Figure 1: Original Image

Figure 2: Bob from Monsters vs. Aliens

Sources:

"Buoyancy." *Wikipedia, the Free Encyclopedia*. 17 Mar. 2011. http://en.wikipedia.org/wiki/Buoyancy/.

"Density." *The Physics Hypertextbook*. 17 Mar. 2011. http://physics.info/density/.

Monsters vs. Aliens. 17 Mar. 2011. http://www.monstersvsaliens.com/.