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Get Wet Report

Introduction

This project was the initial project of the flow visualization course that takes place at CU Boulder during the Spring Semester and is taught by Professor Jean Hertzberg. The purpose of this report is to describe how the phenomenon was visualized and captured by explaining the apparatus, physics, visualization technique and photographic technique used. For this assignment, a single droplet of iodine was dropped into a Pyrex dish containing a layer of canola oil above a layer of water (see apparatus section for more details). The oil was used in addition to water in order to show a flow that's different from the typical umbrella instability that occurs when dropping food coloring or other dyes into water. Iodine was used instead of food coloring because it was more readily available and it was different from what is typically used. Due to the use of the oil and the iodine, and thanks to Daniel Copel's help in performing the experiment, a different phenomenon from what is typically seen was successful in being captured. The final, edited image of the flow can be seen in figure 1, below, and in figure 7 within the Photographic Technique section of the report.

Figure 1 - Final, edited image of phenomenon

Apparatus

The flow apparatus consisted of an 8-inch by 8-inch Pyrex dish which contained 4 cups of water and 2 cups of canola oil. A pipette was used to drop the iodine into the oil from a height of approximately 1 inch, after which the droplet sank down to the bottom edge of the oil, and eventually dropped from the oil into the water, creating the phenomenon that was captured. Both the Pyrex dish and the camera were set up on stands so that the lens of the camera was in line with the edge of the Pyrex dish, allowing a non-angled capture of the iodine droplet as it fell through the water. The edge of the camera lens was located about 3 inches away from the edge of the dish. A desk-lamp, set up next to the dish, shined light from above to provide the lighting. The apparatus set-up can be seen in figure 2, below.

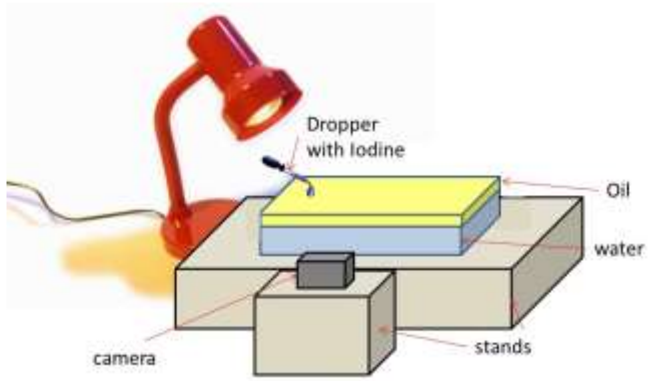

Figure 2 - Apparatus set-up

Physics

There are several different physics aspects taking place in this flow. The first aspect takes place with the interaction between oil and water. At 20°C, canola oil has a density of 0.914-0.917 g/cm^3, and a viscosity of 78.2 mm^2/sec [1], while water has a density of 0.996 g/cm^3[2], and a viscosity of 1.004 mm^2/sec [3]. The lower density of canola oil means that when it interacts with water, it will tend to float on top of it. Additionally, the higher viscosity of canola oil means that any flow that occurs in it will be smaller than any flow that occurs in water. This was observed during the experiment and an image of iodine flowing through oil is included below and in figure 3, below. Another important aspect of canola oil is that it is primarily a triglyceride [1], which means that it is composed primarily of carbon and hydrogen and that it is mostly hydrophobic—does not interact well with water [4]. This helps explain another reason that the canola oil tends to attempt to stay away from the water, and even the iodine.

Figure 3 - Iodine droplet in oil

The next aspect is the interaction is between the oil and the iodine. This interaction can be observed in figure 3, above. As stated previously, canola oil has a density of 0.914-0.917 g/cm^3, and a viscosity of 78.2 mm^2/sec. The density of iodine is 4.94 g/cm^3 [5], and the viscosity is about 7 mm^2/sec [6]. The much higher density of iodine implies that it will sink in oil, while the lower viscosity of iodine implies that the flow of the iodine is higher than the flow of the oil—both factors were observed. After the iodine fell through the oil, it settled on the surface between the oil and the water and stayed there for about a minute (see figure 4). These two interactions describe the physics background of what's happening before the phenomenon that is captured in the image.

Figure 4 - Iodine on surface of oil before it falls into the water

The third interaction, and the one that's the focus of this experiment, is the interaction between the iodine and the water. As noted above, water has a density of 0.996 g/cm^3, and a viscosity of 1.004 mm^2/sec, while iodine has a density of 4.94 g/cm^3, and viscosity is about 7 mm^2/sec Similarly as for oil, the much higher density of the iodine compared to water means that the iodine will sink in the oil—which is observed during the experiment. The higher viscosity of the iodine means that while it will fall through the water, it will flow as it does so—this is also observed during the experiment. The phenomenon observed during this experiment is similar to a research performed by Alex Felce and Thomas Cubaud at Stony Brook University. The joined multiple vortex rings that they observed are formed by a subtle balance between viscous and capillary forces, and are very similar to what is observed during the experiment described in this paper [7].

Although not documented by images in this report, what was noticed was that when the iodine was dropped into only water it assumed an umbrella instability as it fell through the water. On the other hand, by introducing the oil to the experiment, the flow in the water was drastically changed. When the droplet of iodine finally fell through the oil and into the water, it began with no momentum, and the resulting flow is documented in this report. A Reynold's number for a drop is calculated by the following formula obtained from a paper by Bosse et al [8]:

$$Re = \frac{U_d * R}{v} \qquad \text{Equation 1}$$

Where U_d is the velocity of the drop settling, R is the radius of the drop, and v is the kinematic viscosity of the liquid. Since the droplet of iodine fell into the water with no outside momentum/no initial velocity, the above equation is sufficient to determine the Reynold's number. U_d was estimated using the camera settings to be approximately 0.119 mm/s. The kinematic viscosity of the iodine is approximately 7 mm^2/s (from above). Finally, the radius of the drop was approximated as 3.175 mm. Putting all of these values into equation 1 gives:

$$Re = \frac{\frac{0.119mm}{s} * 3.175mm}{\frac{7mm^2}{s}} \qquad \text{Equation 2}$$

This results in a Reynold's number of 0.054. Bosse et al stated that for a Reynold's number less than 1, "the suspension drop retains a roughly spherical shape while settling." [8] This effect was observed while the drop was settling—with a difference being that it started pulling down, creating vortexes, as it was settling (as seen in the figures) —which could explain why the experiment produced the observed phenomenon.

Visualization Technique

The fluids used for the visualization were canola oil, tap water, and iodine. The 8-inch X 8-inch Pyrex dish held four cups of air-temperature tap water, and two cups of canola oil. A single drop of iodine was dropped into the solution for the experiment. The specific Iodine used was a 10% Povidone-Iodine Solution made by TopCare and purchased from Wegmans. [9] The canola oil used was the Kroger Brand canola oil purchased from King Soopers.

Since the image was taken in the kitchen, extra lighting was needed. White paper was placed behind and below the Pyrex dish so that light would be reflected. Additionally, a lamp—the IKEA ESPRESSIVO desk lamp— was used to provide extra lighting. The lamp uses a 12V Bulb, which has a 20W maximum output. The lamp was placed next to the apparatus and the light was shined from above. It reflected off of the paper and provided the necessary lighting for the image.

Photographic Technique

The camera used to capture this phenomenon was a Canon EOS Rebel T3 DSLR camera. The macro setting on the camera was used, with the default settings selected. The size of the field of view is approximately 3” tall by 5” wide. The lens was about 3” away from the edge of the Pyrex dish and the macro mode on the camera was selected. The shutter speed, f-stop, aperture value, ISO speed, and focal length were 1/160 sec, f/4.5, f/4.6, 100, and 29.00mm, respectively. The original, unedited, image has pixel dimensions of 4272 pixels wide by 2848 pixels tall, the intermediate image—the one presented and critiqued on in class—has pixel dimensions of 936 pixels wide by 1572 pixels tall, and the final image—incorporating the comments from the critique—has pixel dimensions of 858 pixels wide by 1032 pixels tall. Refer to figure 5 for the original image, figure 6 for the intermediate image, and figure 7 (or figure 1) for the final image.

Adobe Photoshop CS2 was used to edit the original, and later the intermediate, images. The tools used were: crop, unsharp mask, the spot healing brush, and curves. Unsharp mask was used twice. The first time it was used directly after cropping the image; the amount was 75%, the radius was 5.0 pixels, and the threshold was 0 levels. The second time unsharp mask was used was after going through with the spot healing brush and removing any vertical streaks or imperfections/artifacts to the image; this time, the amount for unsharp mask was 50%, the radius 4.0 pixels, and the threshold was 0 levels. These edits produced the intermediate image seen in figure 6. For the final image (seen in figure 7), the intermediate image was cropped and curves were applied once again.

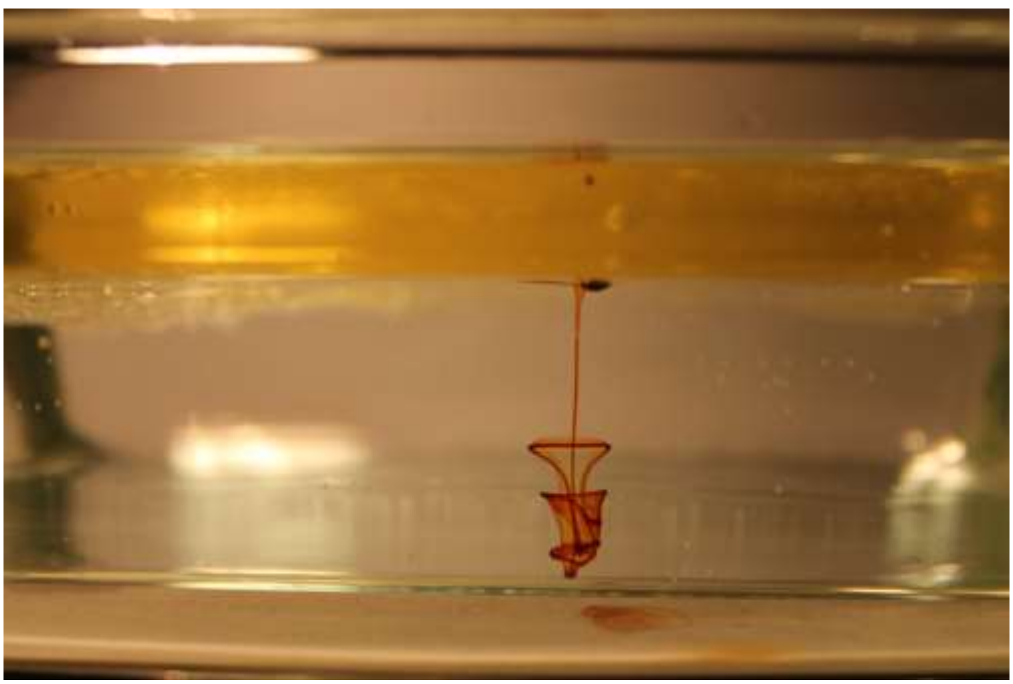

Figure 5 - Original, unedited image

Figure 6 - Intermediate image - presented for critique

Figure 7 - Final image - edited per critique suggestions

Conclusion

The image clearly reveals the phenomenon of iodine falling through water only after having been in oil first. I like how the image has three separate waves/loops that are all very well defined; however I don't like the graininess that's visible in the flow when the image is at full size. I think that the fluid physics are very well shown and defined in this image. My intent with taking and presenting this image was to show the difference in including oil as a medium, and that intent was fully realized. To further develop this idea, a video of the two different flows could be shown and compared—one with the iodine dropping only into water, and the other which reveals the phenomenon described in the paper. While there is always room for improvement—and in this case I would have attempted to replicate the image with better lighting, or more features—I am pleased with how this phenomenon was realized and shown.

References

[1] Przybylski, Roman. "Canola Oil: Physical and Chemical Properties." N.p., n.d. Web. 11 Feb. 2013. <http://www.canolacouncil.org/publication-resources/print-resources/technical-sheets/canola-oil-physical-and-chemical-properties/>.

[2] "Properties of Water." *Properties of Water*. N.p., n.d. Web. 11 Feb. 2013. <http://www.engineeringtoolbox.com/water-properties-d_1508.html>.

[3] "Water - Dynamic and Kinematic Viscosity." *Water - Dynamic and Kinematic Viscosity*. N.p., n.d. Web. 11 Feb. 2013. <http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html>.

[4] Tamarkin, Dawn A. "Lipids." *Lipids*. STCC Foundation Press, 2011. Web. 11 Feb. 2013. <http://faculty.stcc.edu/AandP/AP/AP1pages/Units1to4/epitissmol/lipids.htm>.

[5] Ophardt, Charles E. "Iodine." *Iodine*. Virtual Chembook, 2003. Web. 11 Feb. 2013. <http://www.elmhurst.edu/~chm/vchembook/102iodine.html>.

[6] "PVP-iodine: Povidone Iodine Antiseptic Agent." International Specialty Products, 2004. Web. 11 Feb. 2013. <online1.ispcorp.com/Brochures/Pharma/pvpiodine.pdf>.

[7] Felce, Alex, and Thomas Cubaud. "Division of Fluid Dynamics." *APS Physics*. Stony Brook University, 2010. Web. 11 Feb. 2013. <http://www.aps.org/units/dfd/pressroom/gallery/2010/cubald10.cfm>.

[8] Bosse, Thorsten, Leonhard Kleiser, Carlos Härtel, and Eckart Meiburg. "Numerical Simulation of Finite Reynolds Number Suspension Drops Settling under Gravity." *Physics of Fluids* 17.037101 (2005): n. pag. Web.

[9] Wegmans, n.d. Web. 9 Feb. 2013. <http://www.wegmans.com/webapp/wcs/stores/servlet/ProductDisplay?productId=382881&storeId=10052&langId=-1>.