"Get Wet"

Flow Visualization

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Project #1

Due 9/25/07

Purpose:

The photograph of interest was captured for project one, "Get Wet". The purpose of this project was basically to get our feet wet, or get comfortable with taking photographs of fluid flow phenomena. The intent of my photograph was to capture a fluid phenomenon known as spreading. This is a surface concept, and occurs when two fluid surfaces come in contact with each other. More about this concept will be explained later.

Experiment:

The experiment was setup to show Liquid Paper correction fluid spreading out over the surface of soap water. Shown below in *Figure 1* is a sketch of the experimental setup. The sink was holding approximately 160oz of water, and there was 0.5oz of dial antibacterial dish soap mixed in. All of the fluid from a Hi-Liter brand fluorescent marker was used in the mixture.

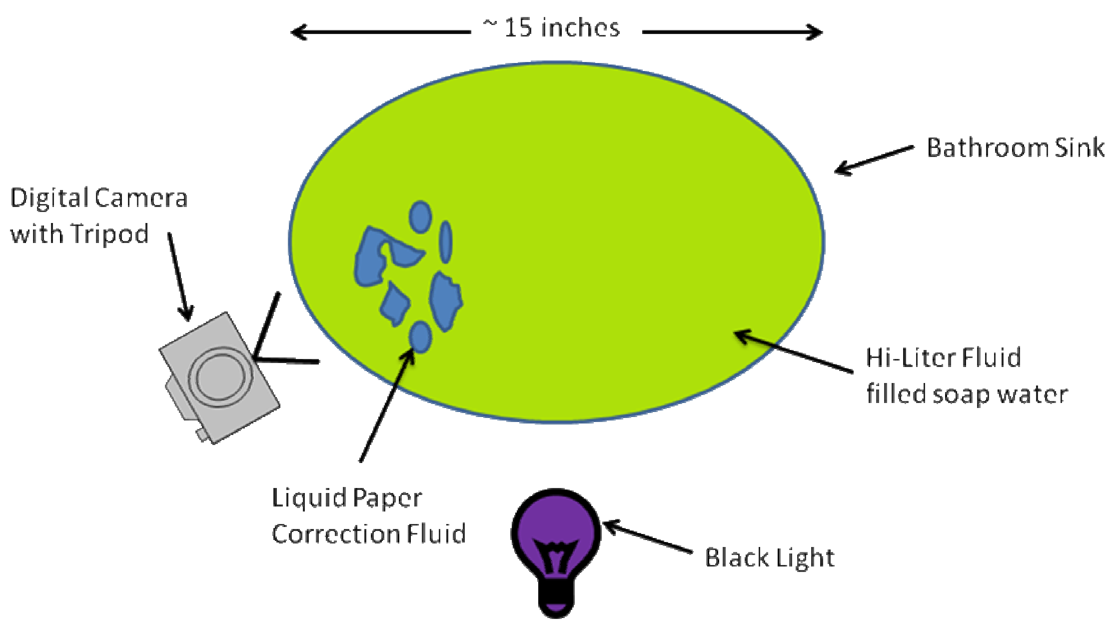


Figure 1: Experimental Apparatus

The required spatial resolution for this experiment would be around 20 lines/inch minimum to capture the smallest flow feature possible. The actual spatial resolution was 72 lines/inch. The field of view does not encompass the entire sink, and has approximate dimensions of 12 inches x 16 inches. Given both the exposure time and approximate spreading rate of the Liquid Paper, an estimated amount of blurred pixels can be calculated. With an exposure time of 1/6 second, and a spreading rate of 1 inch/second, the estimated number of pixels blurred due to time resolution would be 26. Of course this is 26 pixels out of 1920 total in the vertical direction.

Physics:

Practically insoluble substances when placed on the surface of another liquid such as water, will do one of two things. They will either remain as a solid, or they will spread out over the surface. There has to be the right conditions in order for the spreading to occur. The experiment was conducted with clean water, and the Liquid Paper did not spread out over the surface. The addition of the soap to the water allowed the Liquid Paper to spread out over the surface because it increased the adhesion between the two liquids. Stated in *The Physics and Chemistry of Surfaces,* a book by Neil Kensington Adam, the water molecules are always in constant motion parallel to the surface, and it is these motions that cause the expanding movement of the spreading immiscible liquid. The surface and interfacial tensions between the two liquids determine whether or not the top liquid spreads. The Reynolds Number calculation for this type of flow is complex, and must be simplified in the interest of time and report length. Using the fundamental Reynolds Number calculation method combined with some approximated values, it is shown below that the flow is laminar.

$$Re = \frac{\rho u L}{\mu} = \frac{\left(3100\frac{kg}{m^3}\right)\left(0.0254\frac{m}{s}\right)(0.0015875m)}{0.2\frac{Ns}{m^2}} \cong 0.625$$ (Flow is highly laminar)

In this case, ρ is the density of Liquid Paper, u is the approximated velocity of the spreading in one direction, L is the characteristic length (which in this case is taken to be the mean film thickness from start to finish of the spreading), and μ is the absolute viscosity of the Liquid Paper.

Visualization Technique:

To show the spreading phenomena, Hi-Liter fluid was mixed into the soap water for strong illumination under black light. The experiment was run before the addition of Hi-Liter fluid to make sure the spreading wasn't due to the mixture. To capture the flow, direct black light was used to illuminate both the soap water and the Liquid Paper, with no other incoming sources of light. The black light was placed near the bottom of the sink, just out of range from lens flare.

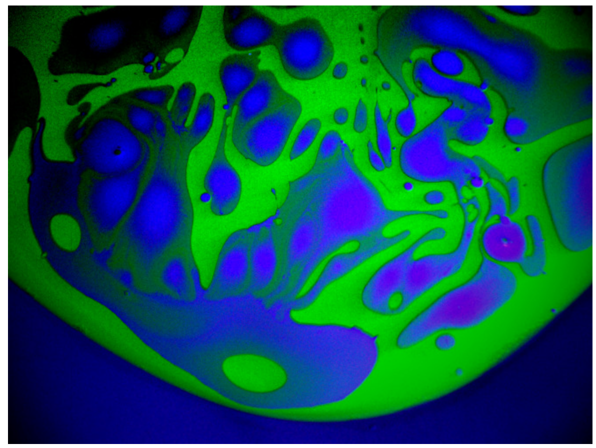
Photographic Technique:

The field of view was no bigger than a bathroom sink. The estimated field of view for the picture was 12 inches in the vertical direction, and 16 inches in the horizontal. The distance from the lens to the surface of the water was approximated to be around 4 inches. The lens itself is a 35mm film camera equivalent, with a 5.8mm – 17.4mm focal length range, and an F-stop range from 2.8 – 5.0. For this specific picture, the focal length was 5.8mm, and an F-stop of

2.8. The camera used in the experiment was digital, taking 2560 X 1920 pixel shots, which is also adjustable. The exact make and model was a Panasonic Lumix DMC-FX7.

The exposure time for the picture was 1/6 second, with a max aperture value of 3.0 and an ISO speed rating of 200. The original photograph was changed using some of the techniques in Adobe Photoshop. The main thing changed in the photo was the brightness and contrast setting. The contrast was increased, and the brightness decreased. A lighting effect was also used to introduce a little more light to the top left portion of the picture.

Before Photoshop



After Photoshop

<u>The Image:</u>

The image itself, beside the fluid physics, reveals a lot. The transparency of the Liquid Paper allows for strong contrasts between thinner and thicker parts of the film. The image flows in the sense that the boundaries of the Liquid Paper fit well with the surrounding flow, as well as the neighboring Liquid Paper bodies. This also shows that the spreading significantly slows when approaching a neighboring film. The use of Hi-Liter fluid in combination with black light illumination proved to really bring out a well defined image, whereas conventional light would not have done so well. This flow phenomenon is a lot more complex than can be described here, and has plenty of room for elaboration and new experiments. The image succeeds in getting the physics standpoint across, and is also aesthetically pleasing.

<u>Resources:</u>

Material Safety Data Sheet. MSDS#: 1391. Sanford Corporation. Bellwood, IL.

Available Online: http://hcpc.uth.tmc.edu/pihome/edu/msds/images/LiquidPaerCorrection.pdf

Adam, Neil Kensington (1968). Emeritus Professor of Chemistry, University of Southampton. *The Physics and Chemistry of Surfaces.* New York. Dover Publications Inc.