Get Wet: Food Dye in Water

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Purpose

Flow Visualization is a surprising intersection of appreciation for art and physical phenomena – it is the interdisciplinary approach to understanding beauty in its aesthetic and scientific form. In this first assignment, Get Wet, the challenge of capturing a physical phenomenon artistically is explored. The primary intent of this experiment is to observe the interaction between food dye and water. The secondary objective of this experiment is to demonstrate surface tension through distortion, and to visually compare two levels of distortion. The third objective of this experiment is to become well-acquainted with the technology used to produce the art and to explore techniques of photography. For this particular experiment, the surface tension created by an overfilled glass of water is illuminated by the addition of food dye. In theory, the surface tension should cause the water to bulge over the rim of the glass. With the addition of a drop of food dye in the water, the camera can capture the interaction between the fluids, and two levels of distortion: 1. the distortion of the dye through the bulge of water above the glass, and 2. the distortion of the dye through the glass surface itself as it dissipates in the water.

Approach

A side view of the set-up for the experiment can be seen below in Figure 1. A detailed explanation of the set-up is provided in the subsequent section. By accounting for the dimensions in the schematic and forming a few educated assumptions, an understanding of the interaction between the food dye and water can be quantified. The impact of the food dye on the water creates a fluid interaction due to the velocity of the dye and the difference in densities of the dye and water. [1] The hypothesis of this experiment is that this interaction will be turbulent. This hypothesis is supported by the image produced and the observations during the experiment, which show the dye in a somewhat chaotic form as it dissipates in the water.[2] In order to prove this hypothesis, first the following assumptions are identified:

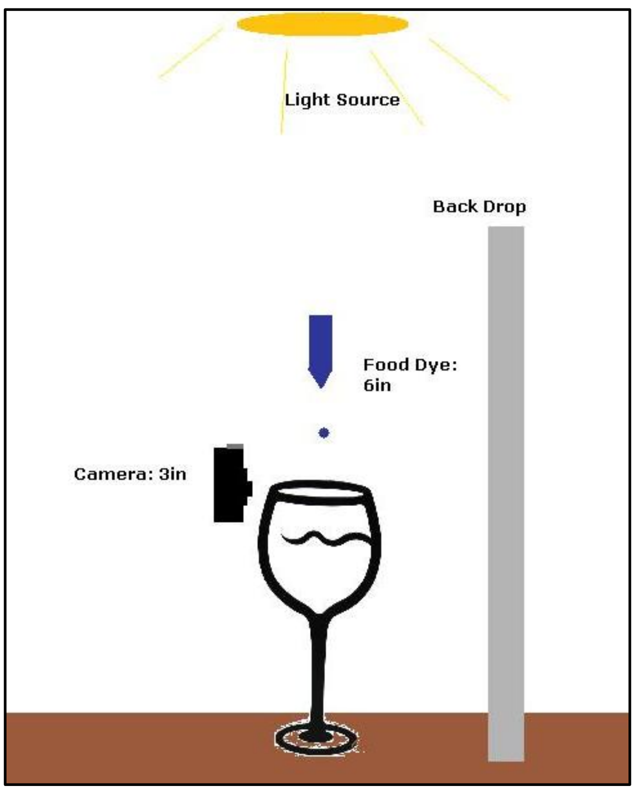


Figure 1. Experimental Schematic - Side View

1. The room in which the experiment takes place is 68°F or 20˚C.
2. Air resistance of the dye falling in air can be neglected.
3. The shape of the dye as it free falls can be approximated to a sphere.
4. Food dye is primarily made of propylene glycol, so this will be the fluid property observed.

With these assumptions, the standard properties and dimensions of the fluids and experimental set-up must also be identified.

Density of propylene glycol: ρ = 1040 kg/m^3 [3]
Dynamic viscosity of water: μ = 1.002 x 10^{-3} Pa*s
Distance between dropper and glass (traveled by falling food dye): 6in or 0.1524m
Initial velocity of the food dye in air: V_o = 0 m/s
Diameter of the dye drop before impact: L = 3/16 in or 0.0047625m
Gravity: 9.8 m/s^2

The primary equation used to indicate the type of flow occurring is called the Reynold's Number equation. The Reynold's Number is a measure of the amount which a fluid is opposing motion versus the viscosity of the fluid.[4] If this ratio is above 2000, the flow can be characterized as turbulent. The equation is shown below:

$$Re = \frac{\rho V L}{\mu}$$

Where ρ is the density of the dye, V is the final velocity of the dye on impact, L is the diameter of the dye drop, and μ is the dynamic viscosity of the water. All values have been listed above in fluid properties, apart from the final velocity of the dye drop.

The final velocity can be found from a separate and simple kinematics equation. Assuming that the drop of dye released from the bottle is in free fall, the velocity of the dye in the instance before it hits the water can be used as the velocity in the Reynold's number.

$$V_f^2 = V_i^2 + (2 * a * d)$$

Where V_f is the final velocity, V_i is the initial velocity, *a* is the acceleration due to gravity, and *d* is the distance from the dropper to the wine glass. Each of these values is known, and can be plugged into the equation to find V_f.

$$V_f^2 = 0 + \left(2 * 9.8\frac{m}{s^2} * 0.1524m\right) = 1.7283\ m/s$$

With this value known, the Reynold's Number can be solved.

$$Re = \frac{\left(1040\frac{kg}{m^3}\right)\left(1.7283\frac{m}{s}\right)(0.0047625m)}{(1.002x10^{-3} Pa \cdot s)} = 8543.18$$

As stated earlier, this value needed to exceed 2000 in order to be characterized as turbulent flow. Because the Reynold's Number is 8543, it the interaction between the food dye and water is turbulent.

Visualization Technique

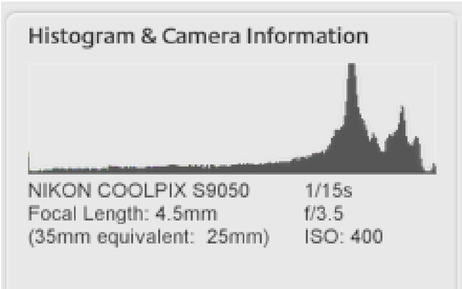
The experimental set-up involves a short list of materials:

- Kroger brand blue food dye (from King Soopers)
- 1 wine glass (household)
- Tap water
- 1 flat, white plastic surface (found among the lighting equipment in Durning Lab)

With the use of the aforementioned materials, household lighting, and a digital camera, the experiment can be recreated. Specifically, the visualization technique employed in this experiment is the use of food dye. This entire experiment was performed on a kitchen counter. The wine glass was first filled with water. A shot glass was used to fill the wine glass with additional amounts of water until surface tension was seen through a dome shaped water bulge. A helper, my good friend Christina Bonfanti, held the flat white plastic behind the wine glass to create a uniform background. Once the camera was in position, a drop of food dye was added to the water by being dropped vertically from about six to eight inches above the water. In the picture produced for this project, only one drop of food dye was added. This experiment was performed on a kitchen counter in a small space between the kitchen sink and cook stove. As a result, the light bulb for the cook stove was turned on to add some light to the picture, additional to the kitchen lights that were already turned on. The flash on the camera was not turned on, and no additional lighting was used in this experiment.

Photographic Technique

The digital camera used in this experiment is a Nikon S9050. Despite its exciting features, a major limitation of this camera is that it does not allow the user to choose the f number or the shutter speed, both of which vary depending on the settings of the camera. The original and final dimensions of the picture are the 4000 x 3000 and 3529 x 2270 pixels respectively. The photo was taken on a standard setting without flash; however, it was taken on a black and white setting. This setting was chosen merely for experimentation purposes. Coincidentally, it ended up being one of the better photos of the intended phenomenon; as a result, it was used despite its lack of original color. Because the room was lit, the ISO was chosen to be 400 (the minimum allowable ISO is 160). Lower ISO values were tested and this value was chosen to be the lowest able to produce a quality image. The camera automatically chose an aperture of f/3.5 and a shutter speed of 1/5 or 0.0667s. Through trial and error, it was discovered that the shutter speed could vary depending on how long the button for picture-taking was pressed. The decision was made to balance my elbows on the counter while holding the camera and keeping still for long enough for the picture to be captured. It was noted that a longer exposure time was producing clearer pictures. The focal length was 4.5mm, and it was 25mm in a 35mm film. The “macro” setting was turned on during this picture; as a result, the distance between the camera and the wine glass was about 3 inches. Once the raw image was imported into Picasa, the photo shop tool used in this project, a few changes were made. First, the image was cropped to focus more on the dye as seen in the bulge of water rather than through the wine glass. Because the picture was already taken in black and white, the highlights and shadows were both increased in photo shop in order to accentuate the interaction of the food dye with the water. The histograms below show how changing the highlights and shadows increased the color spread.



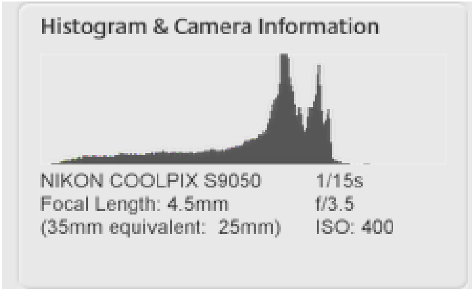


Figure 2. Original Histogram

Figure 3. Final Histogram

While it may have been preferable to have an original color image of the experiment, hundreds of pictures were captured during this particular experimental day. The image chosen for this project was the most favorable, partially due to the black and white setting. Below are the original and final images.

Figure 4. Original Image

Figure 5. Edited Image

Conclusion

This image has many layers. The foreground is out of focus and distorted with the presence of small bubbles from unsettled water and an extra lens due to the wine glass. This blur forces the eyes to move up to the dome created by the surface tension of the water, shown in more clarity. What I love about this image is the sharpness of the tendrils of food dye snaking through the water, and the streaks and wisps of dye that are elongated due to the distortion caused by the bulging water. The black and white coloring with sharper highlights and shadows creates definition and downplays the colors so that the phenomenon itself can be observed with more attention. Of the two scientific intents, both were achieved: observing the interaction between two fluids, and capturing the surface tension and distortion of the dye in the water; however, distortion through the wine glass was lost. This was due to two major set-backs: 1. the focus on this image was chosen by the camera rather than a user, and a tripod was not used for still image, and 2. the bubbles from the settling water distracted from the image because they were out of focus. These two aspects seemed to, in some ways, reduce the quality of the photo and distract from the phenomenon being observed. If this experiment were to be repeated, I would first allow the water to settle for longer in order to eliminate most of the bubbles. I would also use a tripod to support the camera so that it could capture the image on a high exposure with more clarity. Overall, I would like to continue learning about the different settings on a camera and how to change them with intentionality to achieve an effect in an image.

Works Referenced

[1] http://www.physicscentral.com/explore/pictures/cup.cfm
[2] http://sciencebasedlife.wordpress.com/2012/10/17/food-coloring-fluid-dynamics-and-an-awesome-lab-demo/
[3] http://www.inchem.org/documents/icsc/icsc/eics0321.htm
[4] http://en.wikipedia.org/wiki/Reynold%27s_number