Brett Sibel
Flow Visualization
9/28/16

Get Wet Image Report

Introduction

The image shows red and blue dye diffusing in a glass of water. The purpose of this image is to understand diffusion in turbulent flow using physics. Flow visualization can be defined as the process of making fluid flows visible. This visualization allows us to then understand the physics behind the Rayleigh-Taylor instability phenomenon. I was assisted in this image by Daniel Reeves who helped perform the experiment.

Experiment

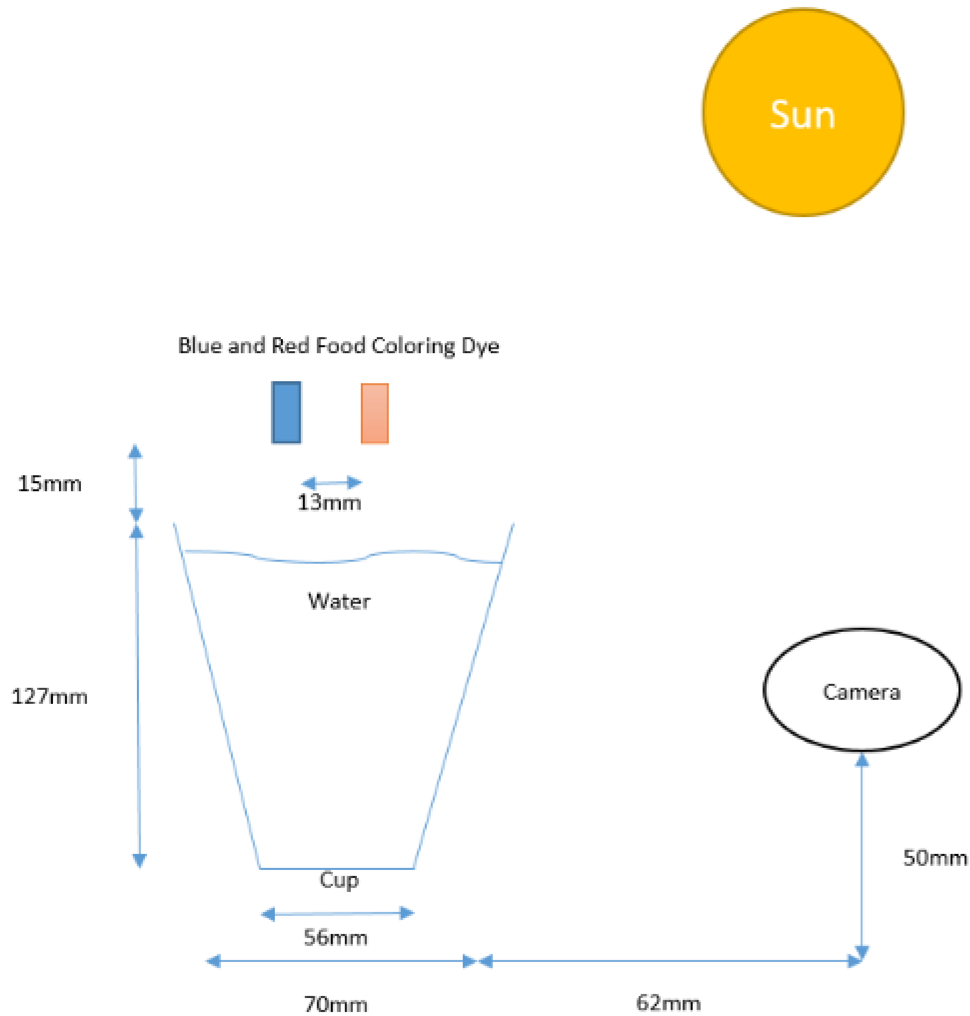
The apparatus used for this image was fairly simple. First a cup was set up on top of a table outdoors at mid-afternoon. The cup was set on a white 8.5 by 11-inch printer paper. White printer paper was also set up on the back south side of the cup as well as the perpendicular east side of the cup. These two sheets served as a neutral background to easily photograph the experiment. Fresh, room temperature tap water was used between each experiment to ensure there was no contamination from outside debris. To start the experiment, one red and one blue droplet was dropped into the cup at the same time. Human error made us had to recreate this part of the experiment quite a few times until the droplets looked like they had dropped at an adequately similar time. Before dropped, the camera started recording the cup. The dimensions of the setup can be found in the sketch below.

The phenomenon seen in the experiment is known as the Rayleigh-Taylor instability. This instability is between two different fluids of different densities where the heavier fluid is pushed by the lighter fluid. The heavier fluid was the food dye, and the less dense fluid was the water. The reason this instability occurs is due to an unstable equilibrium between the interface the two fluids which causes disturbances [1]. As time continues the fluid releases more and more potential energy as the less dense material is propelled upwards. The denser material is also further displaced downwards. This was first studied by Rayleigh over a century before Taylor published his work on the phenomena [1].

To ensure this is turbulent flow, we will find the Reynolds Number for the flow. This equation can be described as the following equation [2].

$$Re = \frac{\rho \bar{V} d}{\mu}$$

We will use the diameter as the diameter of the drop as .003m, the density of ρ of the dye is approximately 1500kg/m^3, and kinematic of water is found to be 0.001002N*s/m^2 at room temperature [3]. The μ of water also is known to be 1.004 (m^2 /s) x 10-6 [3]. When solving for the Reynolds number, we get Re= 4491. This is greater than Re = 1000, displaying turbulent flow.



Visualization

The visualization technique utilized blue and red food coloring dye in water. The food coloring was purchased at Target and its ingredients are water, propylene glycol, yellow 5, red 40, blue 1, red 3, and 0.1% propylparaben. The package itself contained red, blue, green, and yellow colorings. The green seemed to sink too slowly and the yellow seemed to sink too quickly. Blue and red had the most similar densities and material properties so they were used in the final photograph. The water itself is at room temperature (approximately 20 degrees Celsius). The water was taken from the kitchen faucet in my home and given an adequate time to settle so that there were no bubbles disturbing the fluid flow. The photo itself was taken outside to incorporate natural lighting. Photographs were taken from noon to 3:30. The photographs at noon displayed awkward lighting due to the sun being right overhead. The final photograph was taken at 3:30 because the lighting appeared the best.

Photographic Technique

The flow was taken as a still from a video from my iPhone 6 camera. The camera recorded the video at 1080p at 30fps. This technique was chosen because taking just a photo of the plume itself did not give the creative options to pick the most dramatic part of the fluid flow. Also the video itself gave me the ability to understand the visualization as it was happening. The dimensions of the original photo were 269 pixels by 480 pixels, with 269 being the width and 480 being the height. The final image had a 292-pixel width and a 604-pixel height. Aperture and shutter speed was not changed from the camera’s default settings. Editing the photo was done using Affinity Designer. To create the final image, the background and cup was deleted and a white background was added. White was picked due to the brightness of the plume from the natural lighting. Brightness and contrast were also significantly increased in the image.

Critique

The image reveals the kinetic energy of random motion of the red and blue food dye molecules with the water molecules. I love how the image demonstrates the change in concentration gradient, and this effects how the food coloring droplet wants to disperse into the water. Another aspect of the photograph that I really enjoy is how the surface tension keeps the top of the droplet on the surface of the water. The viewer can see that the red and blue coloring have a distinct boundary layer. It gives the image a yin and yang aesthetic. One part of the image I dislike is how I increased the pixel height too much. It degrades the quality of the plume itself making the image look low resolution. This was one of the most consistent comments I got in my critique of the image. To improve this in future iterations of the image, I would remove the background without changing the pixel height and width. I also in the future would use my DSLR camera which was being fixed at the time. The DSLR has a better overall camera, but the iPhone 6 camera did an adequate job in the meantime. A question I do have for the flow was why did the red always sink quicker than the blue. My immediate assumption is that the red food coloring dye is denser as well as has more surface energy. I am happy to fulfil my intent on capturing two different food coloring plumes in water.

References

1. Read, K.i. "Experimental Investigation of Turbulent Mixing by Rayleigh-Taylor Instability." Physica D: Nonlinear Phenomena 12.1-3 (1984): 45-58. Web
2. "Reynolds Number & Pipe Flow." Massachusetts Institute of Technology, n.d. Web. 25 Sept. 2016. <https://ocw.mit.edu/courses/mechanical-engineering/2-000-how-and-why-machines-work-spring-2002/study-materials/TurbulentFlow.pdf>.
3. "Dynamic and Kinematic Viscosity of Water." Essom, n.d. Web. 25 Sept. 2016. <http://www.essom.com/upload/eng_data/34.pdf>