Get Wet Image Assignment

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Flow Visualization - Professor Jean Hertzberg
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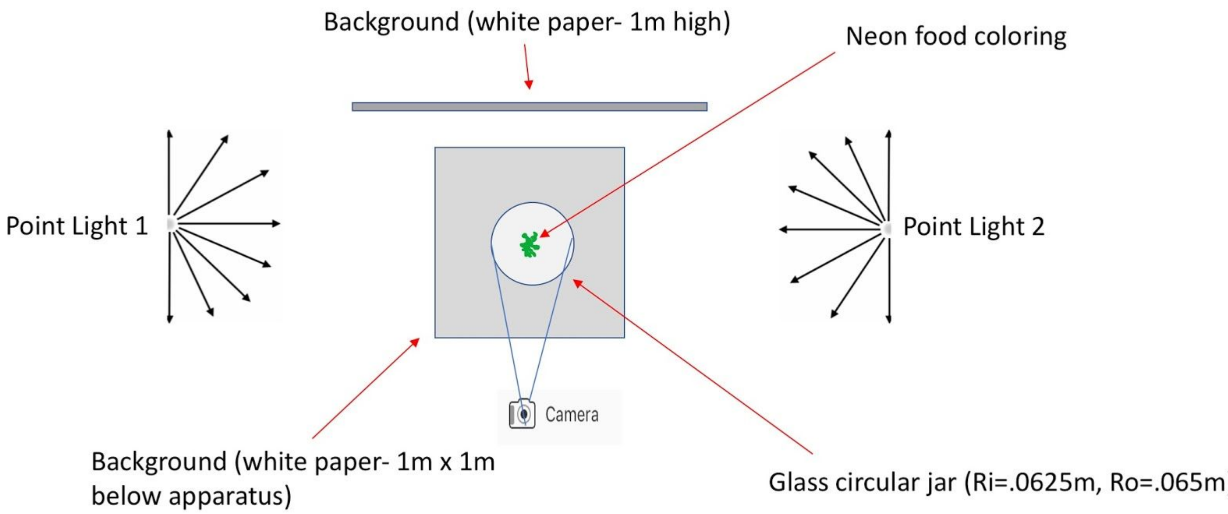
This image represents a beautiful flow pattern created using a simple drop of neon food coloring. As a first project, the focus is a simple procedure that leads to an extravagant image. In this fashion, it is much easier to break down the image and understand the physics behind the art. The intent was to create a phenomenon that isn't easily describable by a student of physics, but easy to recreate for observation. After some background research, the objective was to demonstrate instability and speculate some possible causes for the phenomena.

The flow apparatus consisted of a lab-like setup in an outdoor lighting scene. The lighting was controlled using two flash point-light sources (iPhone 6 flashlight modules) on opposing sides of the camera view (horizontally). The image was shot at 6:00 pm, which is an ideal time for obtaining quality photos in ambient lighting scenarios. The drawing below shows the setup for the experiment, when viewed from above the scene. The point lights reside .5m away from the experiment.



The flow captured consists of neon green food coloring submerged in unfiltered water. The main forces acting on the fluids are buoyancy forces, which are caused by the different densities of the fluids. Since the food coloring is more dense than the water, instabilities are formed in the dye as it diffuses in the water. An important calculation necessary for characterizing the flow is the Reynolds Number, which determines flow patterns and phenomena seen in fluid flow. In order to speculate the Reynolds number of the flow, two successive images were compared in order to calculate the velocity of the flow after being submerged. The two images were analyzed, and the velocity calculation is performed below. The plume of food coloring was carefully examined and a mean diameter of .02m was estimated for the Reynolds Number calculation. The velocity (in water) of the food die was also estimated using frame-rate analysis.

$t = Time\ between\ pictures\ = 1\ second$

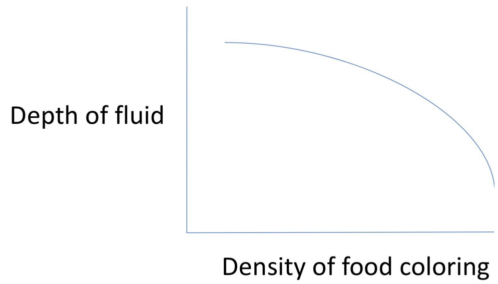
$d = Distance\ of\ travel\ by\ fluid\ (z - direction)\ =\ .02m$

$U = d/t = .02m/s$

$v = 1.13\ cST = 0.00000113m^2/s\ \ (Engineering\ Toolbox,\ Milk\ @68\ degree\ )$

$Re\ = \frac{UD}{v} = \frac{(0.06m/s)(.02m)}{(0.00000113m^2/s)}\ =\ 1061.95$ (Transitional Regime 1000<Re<3000)

The velocity scale was chosen in order to represent the flow accurately according to the resources that were available during the experiment. After calculating a Reynolds Number of 1061.95, the flow is assumed to be in the transitional regime. This means the observer can expect to see small signs of vortex shedding and instabilities in the flow. The phenomena seen in the image can be further described by the patterns in the flow. As seen in the image, when a fluid rests on top of a less dense fluid, an instability arises, and the less dense fluid starts moving upward and mixing with the dense fluid. The density profile of the food coloring is shown below.



Noticeable instability arise in this particular experiment. Known as Rayleigh-Taylor Instabilities, they resemble diffusion of the higher density liquid in the lower density liquid[5] . They are intricate patterns that exhibit almost symmetrical flow patterns (axially) and can look like growing mushrooms in the water. The behavior is also seen in astrophysics (see image 1 below).

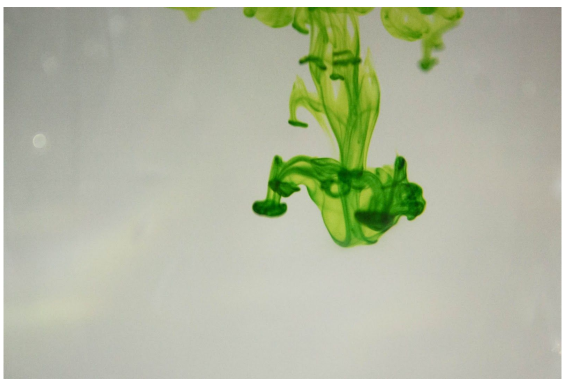
Image 1: Pillars of Creation (astrophysics)	Image 2: Rayleigh-Taylor Instabilities Photo Credit: James Riordon, AIP

Rayleigh-Taylor Instabilities occur because of a dynamic process where two fluids seek to reduce their potential energy[6] . It can be seen in the turbulent regime, and since the Reynolds number for this experiment was in the transitional regime, it is concluded that these instabilities are likely depicted in this Image Assignment. These instabilities are characterized by small vortex shedding of the the dye in water.

The visualization techniques used in the image capture is a technique of dye-dropping. As a simple setup, the materials necessary include food coloring (sourced at any local grocery store), a circular glass jar, and unfiltered water. Relevant lighting includes ambient lighting from the sun, as well as point flashlights from two iPhones. The camera flash was not used in the image capture, and the intensity of sunlight was limited by performing the image capture at 6:00 pm to boost contrast and clarity.
Several techniques were used to isolate the phenomena in the flow. The ISO was set at 800 to limit noise in the image. The Image was shot at 1/80 of a second, and the aperture was set at f/5.6 because depth of field was not of concern since the objective was to isolate one droplet of

dye from the background distractions. A small f-number would allow for this distinction. The field of view was set from a 55mm lens, and was calculated to be .1m x .05m. The distance from object to lens was approximately 0.025m. The type of camera used was a Canon Rebel XSi digital camera. The pixel dimensions of the original image were 3842 (width) x 2561 (height) in pixels. After enhancement, the final image pixel dimensions were 3271 (width) x 2181 (height). Finally, in order to enhance the image, a series of processes were performed. The original image was brought into Adobe Lightroom to increase clarity and exposure, as well as sharpening the image and reducing noise. It was then imported into Adobe Photoshop where levels were adjusted in an effort to decrease shadows and increase contrast.

The original and final images are shown below.



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The image reveals some fascinating fluid phenomena. For a start, instabilities are clearly visible and show specific patterns that represent Rayleigh-Taylor Instabilities. The high contrast and vibrant colors make for a beautiful image, while the white background promotes detail in the fluid flow. Other phenomena depicted in the image arise, which leads to interesting speculation. Some questions that arise are, how do the instabilities maintain such beautifully intricate patterns? And, what causes the symmetry in the Rayleigh-Taylor Instabilities? The answers to these questions can be examined with more research. Overall, the intent of this experiment was realized, and the image capture was transformed into a thorough discussion of flow visualization. Developing the experiment further would require accurate velocity measurement tools, as well as better control with the dye dropping action.

Cited Sources

1. Admin. "Eagle Nebula – Messier 16." Constellation Guide. N.p., 26 Aug. 2013. Web. 25 Sept. 2016. (Image A)

2. Riordon, James. "My Cup Runneth Down." Physics Central. American Physical Society, 2016. Web. 25 Sept. 2016.

3. "Liquids - Kinematic Viscosities." Liquids - Kinematic Viscosities. N.p., n.d. Web. 25 Sept. 2016.

4. Hill, Kyle. "Food Coloring, Fluid Dynamics, and an Awesome Lab Demo." ScienceBased Life. N.p., 17 Oct. 2012. Web. 20 Sept. 2016.

5. Jacobsmeyer, Brian. "Mixing Physics: Rayleigh-Taylor Instabilities." Physics Central. American Physical Society, n.d. Web. 18 Sept. 2016.

6. Cook, Andrew. "Rayleigh-Taylor Instability and Mixing." Scholarpedia. N.p., 209. Web. 23 Sept. 2016.