Injected Art

Anthony Johnson

Team Photo 1 Report

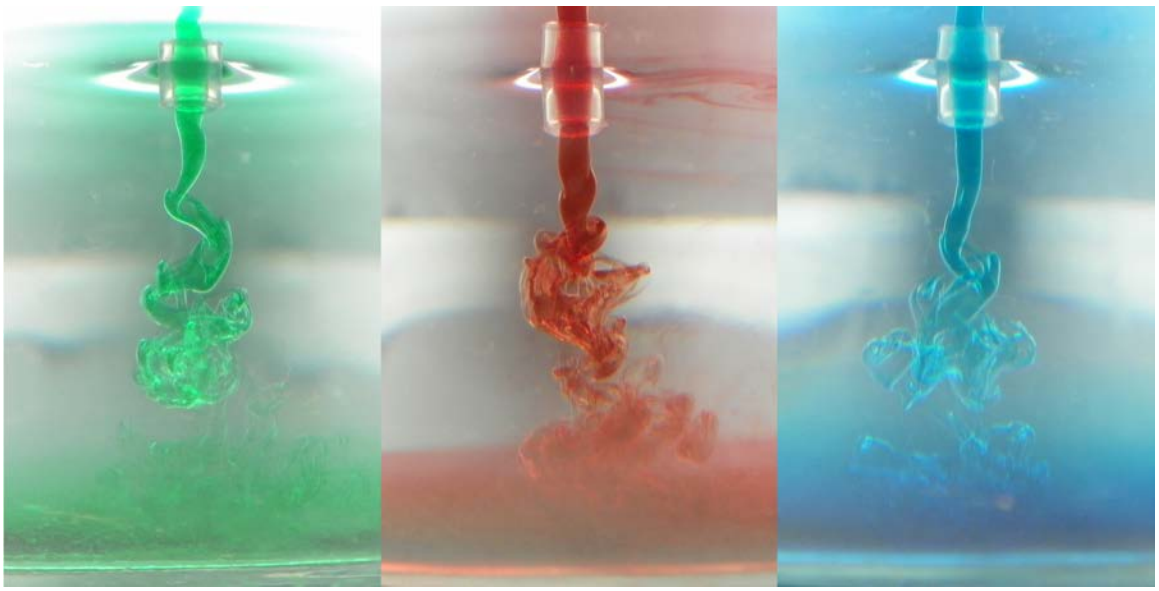

Image Description:

The effect of saltwater falling and subsequently mixing in freshwater is a flow phenomenon found on a global scale. Whether this comes by way of a freshwater river meeting the ocean at a coastal mouth of the river creating an estuary or simply salt crystals dissolving in boiling water, it produces a fluid dynamic visualization that is not only beautiful and unpredictable, but one that demonstrates physics and dynamic principles of the different fluid compositions. The intent of the photos aligned in the cover image was to demonstrate this interesting phenomenon in a way that is both artistically appealing and scientifically revealing. The effects of this mixing were increased through the addition of different colors being mixed in a super-saturated salt solution, which was injected into a glass of cool, calm freshwater.

Method for Capturing Phenomenon:

The method for capturing the fluid dynamics of salt water being introduced to a container of freshwater was fairly simple and straightforward. The photographic setup began by taking regular tap water and bringing it to a boil in a pan. Un-iodized salt was then added to the boiling water until no more salt could be dissolved in the liquid, i.e. salt remained on the bottom of the pan no matter the amount of agitation applied. Un-iodized salt was used because it is relatively free of addition impurities that are not commonly found in seawater or other naturally occurring saltwater sources. In addition, the un-iodized salt dissolves more completely in freshwater and can therefore be used to reach a higher level of saturation. Three cups were then filled with the super-saturated saltwater. Each container was then dyed with food coloring to provide contrast in the clear freshwater. The super-saturated dyed saltwater was then placed into a syringe that would allow the flow of the saltwater to be controlled. Additional lighting came by way of an overhead flashlight hanging roughly 1 foot above the glass as well as the use of the diffused flash from the camera. This syringe was then placed into the glass of cool freshwater and then slowly forced out to produce the desired instability. At that very moment, photos were taken in an attempt to capture the fluid motion and characteristics. This was then repeated several times to ensure quality photos were obtained. The next dyed solution was then given the same procedure while ensuring the focal length and image frame was relatively constant. Once each of the dyes photos was complete, they were combined using the Gimp software to produce the series of images present in the cover image. A representation of the photographic apparatus is displayed below.

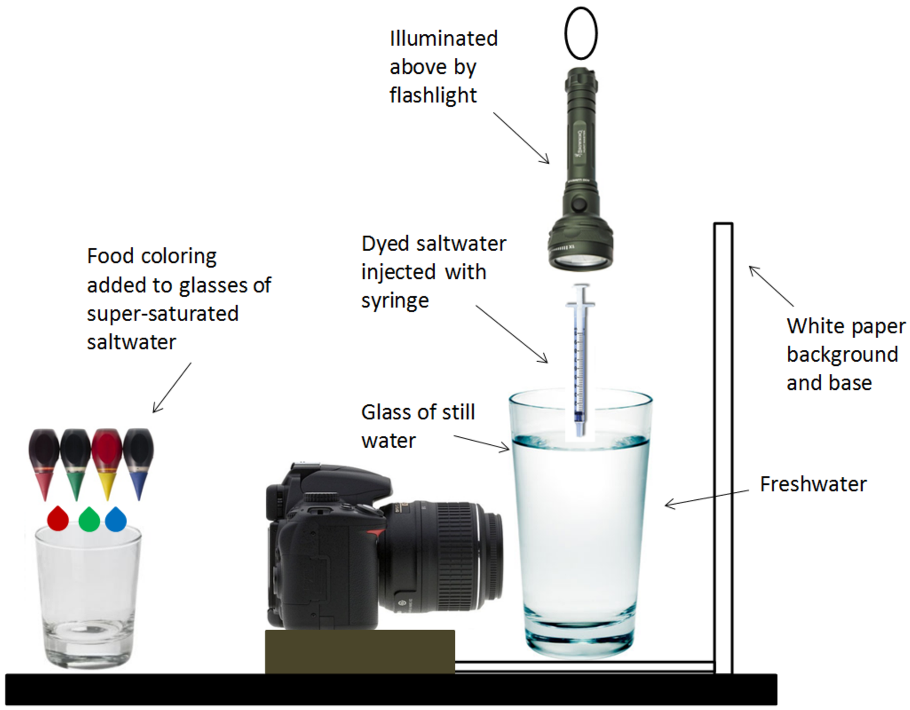

Figure 1: Photographic apparatus

Fluid dynamics and phenomenon:

The primary fluid dynamics presented in this image is that of the variations in density, buoyancy and sinuous instability caused by the mixing of saltwater with freshwater. In the image, this instability is represented in the area just below the nozzle of the syringe in which the flow disperses and diffuses into the freshwater as it reaches the base of the glass. This instability occurs due to the fact that the dyed saltwater has a higher density then the surrounding water (water @ 20 ˚C = 998.2 Kg/m^3, saltwater @ 20 ˚C = 1027 Kg/m^3) [1-2]. Once the saltwater makes contact with the water, this change in densities combined with gravitation force, drive the dyed saltwater to the bottom of the glass of water. This downward driving force disrupts the jet of the saltwater coming from the syringe and rapidly results in the dyed saltwater being perturbed and unstable. The Instability from this driving force causes the release of potential energy, which inevitably deforms the saltwater jet causing the sinuous instability seen at the base of the glasses in the cover image. Near the base of the glass, you see a small-scale representation of an estuary, which is simply an area where freshwater, and saltwater is mixing[3]. To clearly define the fluid flow characteristics present, the Reynolds number can be calculate. This Reynolds number indicates whether the fluid is considered laminar or turbulent which in turn provides insight into whether there are viscous (laminar) or inertial (turbulent) forces primarily acting on the fluid. The Reynolds number calculation is seen below.

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

- μ = saltwater viscosity @ 20 ˚C[5] = 1.08 $x10^{-3}$ N s/m^2
- ρ = saltwater density @ 20 ˚C[5] = 1027 Kg/m^3
- L = characteristic length = .0508 m (2 in)
- V = mean velocity ~ .006 m/s

This results in a Reynolds number of 289.84, which is much less than the critical value of $5x10^5$ where laminar flow translates into unstable turbulence. This indicates that the flow is laminar and demonstrates that the chaotic nature of the dyed saltwater injected in the freshwater is due primarily to the forces and physics of the sinuous instability as well as the variations in densities and buoyancy of the two liquids.

In addition to the sinuous instability present in the mixing of the saltwater jet with the freshwater reservoir, variations in buoyancy are evident in the image. Freshwater is less dense and therefore floats on the surface of the saltwater in the absence of outside mixing such as that of the wind or tide fluctuations that occur in nature. This was exposed in the photographic setup in which the saltwater was directly injected to the base of the glass, which, besides the mixing caused by the force applied by the nozzle, remained relatively separate on the bottom[4]. This demonstrates the principle that saltwater applies a stronger buoyant force then that of freshwater, and when combined with the increased density of the saltwater results in the freshwater floating ominously over the bright colored saltwater.

Photographic technique:

The photographic technique used to make this image was limited due to the use of a Kodak easyshare Z981 which is in essence a point and shoot camera. The camera saves its pictures in a digital format with a pixel quality of 14.1 megapixels. Though the camera has the option to adjust the exposure time and ISO the two cannot be adjusted at the same time. The selection was made to use a faster exposure time in an effort to obtain a clear image of the mixing of the saltwater flow into the freshwater pool. The ISO setting was at 400, which seemed to be appropriate for the photograph and additional lighting. The exposure time selected was 1/1600 s, which provided limited motion blur and an image that was neither over nor under exposed. In addition, this high shutter speed was used to capture more detail of the saltwater jet in the freshwater since the fluid phenomenon occurred quite rapidly as well as dissipated rapidly. The F-stop information is not available for my camera. The approximate frame size of the image is roughly one inch wide by three inches tall given the camera was nearly touching the wall of the glass containing the freshwater. Additionally, due to cropping, this image size was obtained.

There was very little post processing done to this image. This was impart due to the fact that the coloration of the dyed super-saturated saltwater in contrast with the clear freshwater was found to be quite appealing and demonstrated the natural beauty of the physical system and mixing phenomenon. In addition, in experimenting with post processing, the image tended to lose detail and/or clarity of the phenomenon being demonstrated. The only post processing executed was that of cropping the images and resizing then to have a relatively constant frame size. Once the cropping and resizing was complete, the images were combined to form one image with three different flows.

Conclusions:

Overall I feel this image captures the fluid phenomenon present when saltwater is forcibly mixed with freshwater including that of sinuous instabilities present when the saltwater is forced through the nozzle of the syringe. This image reveals the complex and unpredictable nature present in the natural phenomenon of saltwater mixing with freshwater. In addition the Reynolds number presented above also indicates that the saltwater fluid flow acts in a manner similar to other liquids with buoyancies and densities that differ from that of pure freshwater. In the case of this image, post processing resulted in loss of clarity and definition and therefore lose of the fluid flow detail and therefore the image was left in a more natural form to not only provide the clearest image of the fluid phenomenon, but to provide a natural aesthetically appealing image. One question that was developed through performing this project was why, if the freshwater glass was still and calm, do you get such unpredictable shapes and patterns in the fluid flow? I think this question can be answered when you consider the small forces or variances within the procedure that result in large fluid motions and instabilities. If I were to attempt this image again, I would try to make the dyed saltwater more vibrant maybe by using a reflective agent or dye that will glow in the presence of a black light. In addition, varying the speed of the flow between each color could provide further insight into the fluid dynamics displayed in the photo. I feel this photo fulfilled my intentions and is not only aesthetically appealing but displays fluid physics that were surprising to me and before this project, relatively unknown by myself.

Bibliography:

[1] "Water - Density and Specific Weight." *Engineering ToolBox*. Web. 19 Feb. 2012. <http://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html>.

[2]"Bergman, Jennifer. "Density of Ocean Water." *Windows to the Universe*. Web. 17 Mar. 2012. <http://www.windows2universe.org/earth/Water/density.html>.

[3]Oberrecht, Kenn. "Mixing of Fresh and Salt Water." University of Oregon. Web. 17 Mar. 2012. <http://www.oregon.gov/DSL/SSNERR/docs/EFS/EFS33mix.pdf?ga=t>

[4]Sullivan, Chris. "Chronicle of an Older Diver." *Chronicle of an Older Diver*. Web. 17 Mar. 2012. <http://deepstop.wordpress.com/2009/02/26/buoyancy-salt-water-vs-fresh-water/>.

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