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Get Wet - MCEN 5151
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The first project of the Flow Visualization class was titled “Get Wet.” As the theme suggests, we were to take a photograph of a fluid flow in a controlled setting. The goal was to provide a fascinating photo that could be described by engineers and could be reproduced. The first idea was to use Mentos in a soda, but I skipped that since I wasn’t confident in properly capturing the reaction and bubble flow in a dark fluid. The idea that was used required an aquarium “airstone” that had three LEDs on it and aerated the water with air bubbles. The velocity of the air bubbles through the water is an interesting flow, and the bubbles beautifully captured the light colors as they moved. The image is very striking with the defined blue, curvy lines that have intertwined white streaks and red dots.

The flow visual that I produced was accomplished by using a ten gallon fish tank and a three colored LED light with air pressure. The fish tank was filled with approximately 12 inches

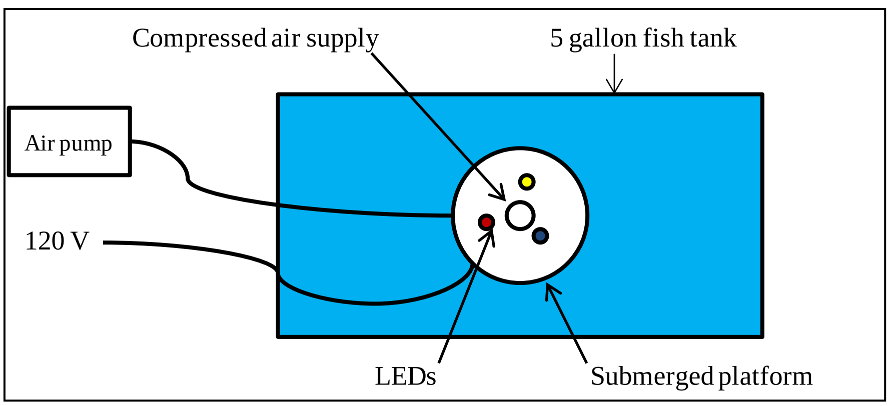

Figure 1: Apparatus Setup

of water, and the three LED airstone (submerged platform) was placed on the bottom in the center. The airstone used is easily available at any pet shop. The airstone is connected to an air pump with a flow rate of 0.6 liter per minute and a valve to control the rate supplied to the airstone, and the LEDs cycled automatically once plugged in to provide various colors. See Figure 1 for a top view of the setup.

The image captured shows a very interesting fluid flow. The bubbles are racing towards the surface due to the buoyancy force since the density of air is significantly less than water. The bubbles are pulling water from the bottom upward with it, creating a continuous rotating flow. The flow is turbulent since the Reynolds number for this flow is calculated as:

$$Re = \frac{UL}{\upsilon} = \frac{\left(5.3\frac{ft}{s}\right)(1\ ft)}{1.06\ x\ 10^{-5}\ ft^2/s} = 5\ x\ 10^5$$

The length scale of 1 foot was chosen because the depth of the water was only 12 inches, or another way to say it is that the bubbles only had 12 inches to travel. The bubbles velocity was calculated at 5.3 ft/s since they traveled roughly 8 inches during the shutter speed of 1/8 second. There is some vortices on the outside of the air bubble jet that is probably caused by the rotational flow created in the tank, shearing the fluid being pulled up by the jet.

This flow is called a bubble jet by various texts and is commonly used for destratification of reservoirs to increase the dissolved oxygen in the water.[1] Most of the kinetic energy of the air leaving the airstone is rapidly dissipated in the turbulent shearing of the liquid and generation of new surface area.[2] This turbulent shearing can cause a Kelvin-Helmholtz instability as is shown in Figure 2 and could possibly be the flow on the outside of Figure 4. Kelvin-Helmholtz (K-H) instability is a classic type of instability generated in density stratified shear flows.[4] The instability develops when small waves at the region of steepest density gradient becomes unstable and begins to roll up into the characteristic K-H billows.[4]

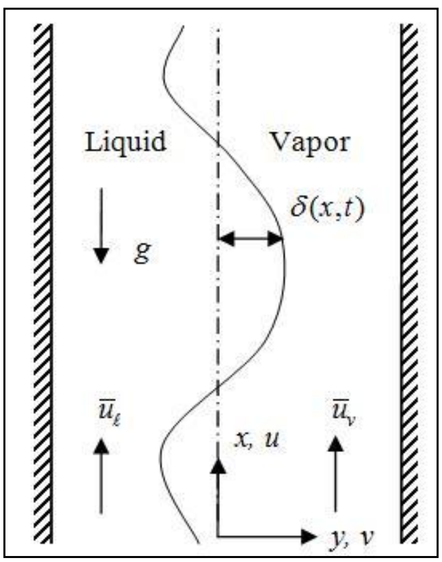

Figure 2: Kelvin-Helmholtz instability in vertical liquid-vapor interface for concurrent flow[3]

The visualization technique used was the LED lighting on the bubbles as they rise through the water. This provided a pleasing image of path lines. The apparatus was set up on a kitchen table and had a black cloth placed as a backdrop. The picture was taken with no light at night in order to capture as much of the LED light as possible on the bubbles.

The size of the field of view was very small, approximately one foot squared since the image itself was small. The photo was taken roughly six inches from the flow, or less than an inch from the tank. The camera used was a Canon PowerShot SD870 IS and was set to the Digital Macro mode. The F-stop was f/2.8, and the focal length was 5 mm. The exposure time was 1/8 of a second, and the ISO was set to 800. The original image was 3263 pixels wide and 2448 pixels high.

The image was minimally manipulated only to eliminate reflections and define lines. Canon's photo utility program, Zoombrowser EX, was used to darken the background to eliminate the reflection and better define the path lines. Then the blue was slightly brightened to again better define the path lines, and the red was increased to bring out the red "dots".

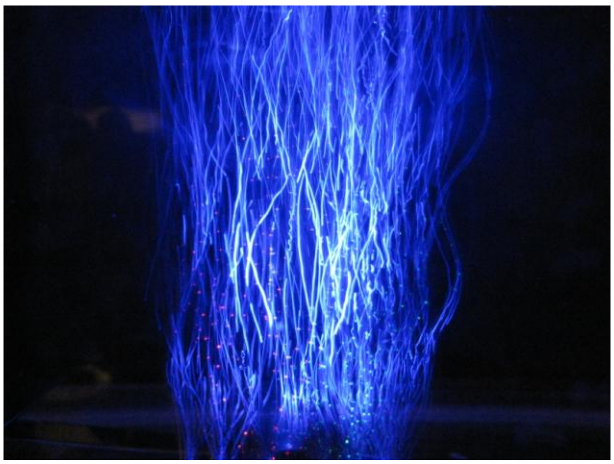

Figure 3: Original Photograph

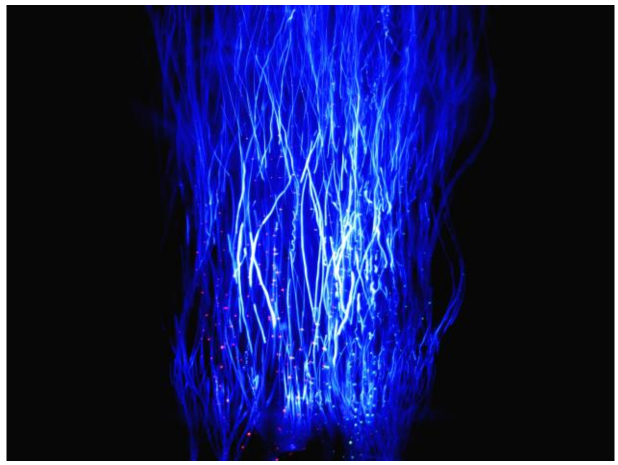

Figure 4: Final Photograph

This image reveals the path that the bubbles took from the airstone to the water surface. I really enjoy this image and am very pleased with its turnout. The fluid physics is well shown by following each path line. My intent was fulfilled with this photo. I would want to have better clarity and elimination of light. I would also want to capture different colors. This idea could be pushed further by introducing a type of cross-lighting that goes horizontal. The purpose would be to further expose the fluid flows and gain additional information to verify its description.

References

[1]H. Helfer, "Influence of Air-Bubble Plumes and Effects of Climate Change on Reservoir Evaporation," Griffith University, April 2012. https://www120.secure.griffith.edu.au/rch/file/bd8c9734-dd8f-9325-7612-856f064a43ea/1/Helfer_2012_02Thesis.pdf .

[2]N. Ismail, "Guidelines for the Design of Air Bubble Systems," University of California – Berkeley, 1971. http://journals.tdl.org/icce/index.php/icce/article/viewFile/3220/2884.

[3]Thermal-Fluids Central: https://www.thermalfluidscentral.org/encyclopedia/index.php/File:Kelvin-Helmholtz_instability_in_vertical_liquid-vapor_interface_for_concurrent_flow.jpg.

[4]S. A. Socolofsky and G. H. Jirka, "Instability", 2004, http://www.ifh.uni-karlsruhe.de/lehre/envflu_II/Students/ocen689ch11.pdf.