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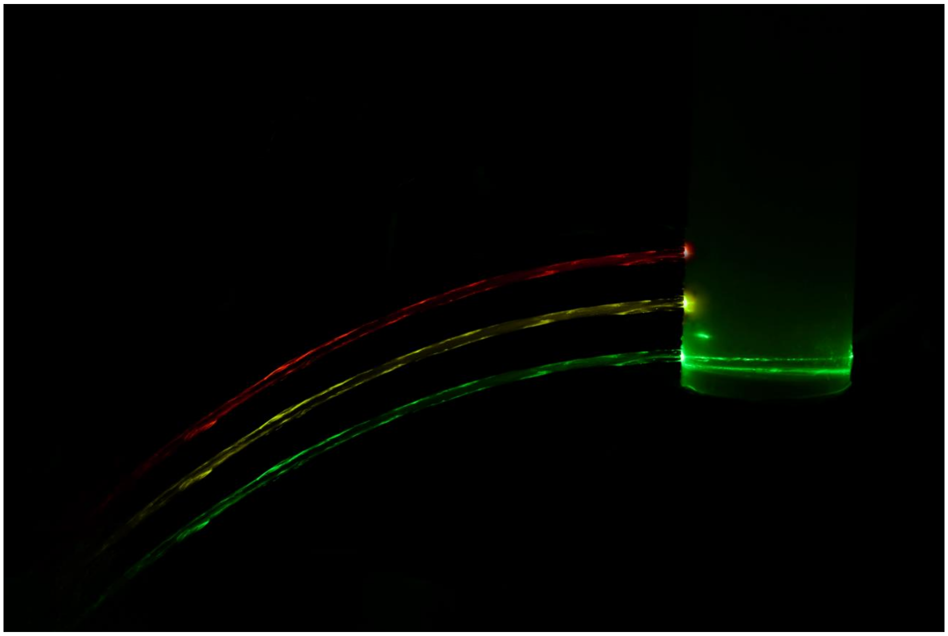
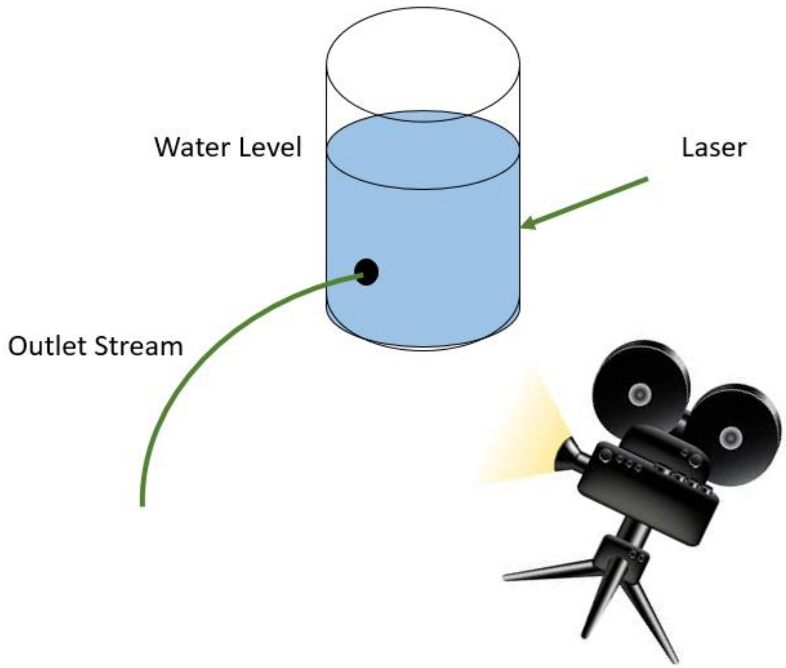
Team Second Report
MCEN 4151 – Flow Visualization
5/6/2018

Internal Refraction of Lasers in Water Streams



This image is an edited image from an internal refraction experiment. The experiment was to observe the colors shown through a laminar stream of water exiting an acrylic cylinder. I worked with my team, including Luke Collier, Zachary Marshall, Philip Nystrom, and Yousef Shashtari, to set up the experiment and take several still images. The idea was to shine a laser pointer through a clear cylinder with outlet holes that would create laminar flow. The laminar flow ideally would trap the laser light and reflect it due to the angle of incidence. Based on our results, the internal refraction was successful and the water trapped the light. We initially set out to shine a red, yellow, and green laser through different holes to create a "stoplight" appearance, but I will address some issues with that later.

The diagram below shows the setup of the camera, laser, and flow stream made using Microsoft PowerPoint. The team used an acrylic cylinder with a round hole in the lower edge. When filled to the top, the water was forced out of the hole at high velocity. Directly opposite from the hole was a powerful laser pointer aimed directly through the stream. The light from the laser entered the stream, reflected internally off the stream boundary, and stayed in the stream to illuminate the entire water flow.



Setup of Experiment

The science behind the experiment is based on reflection properties and laminar flow properties. The concept is parallel to fiber-optics – as the light particles enter the stream, they reflect off the boundary and remain inside the stream rather than shine through. In the case of fiber-optics, those photons transmit data, whereas in our experiment we are transmitting light. The result is the transmission of photons through the flow until the stream becomes turbulent and the critical incident angle fails to trap the light.

Another scientific phenomenon to observe is the velocity of the stream. This is based on the pressure at the depth of the hole in the cylinder. Pressure is related to depth as shown in the equation below:

$$P = \rho g h$$

Where "g" is the gravitational constant (9.8 m/s^2), "h" is the depth of the water (approximately 20 cm), and "ρ" is the density of the fluid (1000 kg/m^3). Multiplying together, the gage pressure is roughly

$$P = 1{,}960\ Pa$$

This value should be added to atmospheric pressure, since we also have air pressure on top of the liquid surface giving a total pressure of

$$P = 103{,}285\ Pa$$

Based on the flow, we see that this pressure does not give a high enough Reynold's number (proportional to the velocity) to create turbulent flow.

One note to make about my final image is the post-processing to add the additional streams in the alternate colors. The additional colors show similar, parallel flow as the bottom stream. This would not be observed in a true experiment if there were several holes. Since the holes are at slightly different heights the "h" value would be different for each, which would change the velocity of each outlet. During post-processing I added these streams to create a "stoplight" effect, but it admittedly appears to break the laws of physics.

The FOV on this image is approximately 2 feet by 3 feet. I chose this region to focus on the specific stream here and reduce the background distractions. The flow was about 3 feet from the camera, which used a standard 18-55mm lens. I used a Pentax K100 for the shot shown above. In the end, I used Gimp for the color enhancements and additional streams. I was able to recreate the stream with the clone tool and a hue change to create the red, yellow, and green of a stoplight.

I like how the image came out, though I will admit I was overlooking the physics of true flow when I added the extra streams. This picture is simply a learning experience for me in Gimp to create something that is not truly possible, but I believe it looks interesting and displays the original goal of the experiment.