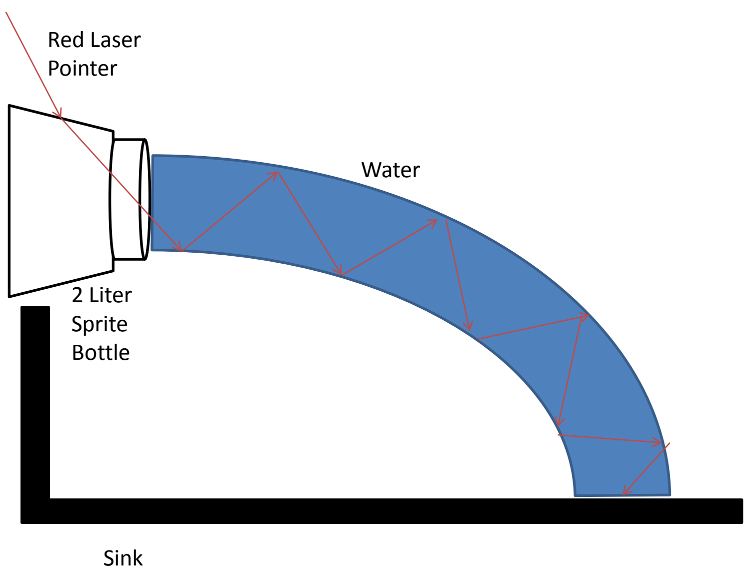
Benjamin Pacheco
Flow Visualization Spring 2012
04/3/2012

Team Image 1

For the initial Team assignment as a group we decided to use the flow visualization of lasers to obtain images. The intent for my image was to use the laser and demonstrate how the idea of total internal reflection works. More so the apparatus that I devised will show how at the right angle the laser beam will enter a flow of water and use it as a director to determine where the laser beam will end up. The effect trying to be demonstrated is that based on the index of refraction that the two different materials, air and water, that the laser light will be reflected inside the water at an angle and follow that to a directed area. In order to achieve this effect it took multiple tries due to the fact the material of the bottle also bends the light and the apparatus used to handle the laser pointer was my hand and it took many tries to get the laser at the right angle and steady enough to physically observe this effect. Ultimately, I end up finding a suitable angle and used some fluorescence from a highlighter to help visibly see the total internal refraction within the clear water.

The experimental setup I used can be referenced in the following schematic below.



Schematic 1

Initially, I started out by trying to find a green laser because it would be much easier to see it reflecting in the water. But I was not able to find a green laser and had to settle with a regular red laser pointer. I eventually then decided to use water as my medium because it is relatively easy to obtain and somewhat easier to calculate. My method was relatively simple, I used a 2 liter soda bottle with a hole

Benjamin Pacheco
Flow Visualization Spring 2012
04/3/2012

punched in the bottom of the bottle so air could escape and I could get an uninterrupted flow of water from the spout of the bottle. Next I filled up the water bottle and added 1 oz of pink highlighter fluid because it cause the laser to scatter more which in turn causes it to more easily seen by the human eye. Next step was to turn out the light and shine the laser towards the neck of the bottle to get an angle at which total internal reflection would happen. Overall there were many pictures taken and multiple pours but the final image was selected due to the fact it clearly indicated that total internal reflection was happening. The most obvious part was that in the photo one can see the one laser beam split into two by the bottle itself and how one at a steeper angle went straight down while the other flowed with the direction of the stream of water.

Even though this phenomena is fairly complicated in experimentation the calculations to determine the angle of total internal reflection is relatively simple. The whole idea behind TIR (total internal reflection) can be numerically illustrated Snell's Law. The idea is fairly straightforward in that the angle of TIR depends on the angle of the incoming laser as well as the two different indices of refraction that one is trying to measure.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$ [i]

Where the n values signify the two different indices of refraction and the two different theta (θ) values are the two different angles. In order to solve for that critical angle of reflection the equation needs to be rearranged into the following form.

$$\theta_{crit} = \sin^{-1}(\frac{n_1}{n_2} \sin \theta_1)$$

From this we are then able to deduce a critical angle with some known values. We start of by using the index of refraction of air n_2 which is 1, and the index of water n_2 which is approximately 1.333. We can then make the assumption that the angle in the water is approximately 45˚ which would bring the critical angle of laser pointer to 70.5˚ clockwise from the horizontal.

The most crucial part of the visualization of TIR was getting the room dark enough and finding something that could help the laser become more visible to the human eye. The simplest way to do this was to find a liquid material that would not change the refractive index of the water. It seems that regular old highlighter fluid has near the exact same refractive index of water and at the same time could make the beam more visible to the camera. Also it seemed that it helped that the highlighter fluid was red because the camera ended up receiving a better signal.

This particular image was taken with a field of view that was roughly 1 ft away from the lens of the camera and approximately within a 4sq ft area. For this image the resolution was 5184 by 3456 pixels, with an F-stop of f/3.5. The ISO used for this image also had to be fairly high in order to capture the image in a very dark room it was set at 1600. Then the image was taken with an exposure time of 2 sec, and at a focal length of 20mm. Once the photo was imported into a graphics interface program the levels, and contrasts were adjusted. Then once a fairly bright visible image was obtained I created a negative parabola in the curves to cause the brightest pixels in the image to invert and change colors. Overall this effect allowed for distinction between where the laser was pointed and what light was diffracted from instabilities in the stream of water.

Ultimately, my image was ideal for showing how total internal reflection works with two different materials of different indices of refraction. In all, the image easily showed that with the right angle the laser beam will stay in the stream of water and use it as a director. My intent then became fully recognized by having both the original laser pointed one place and being able to see how the TIR led the laser to another place. Also, in the future I would like to explore TIR with other materials to see how it reacts but when experimenting I would also like to be able to acquire a green laser pointer that can already be seen by the human eye so no dye (highlighter) needs to be used.

References:

"Refraction of Light", n.d. http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/refr.html.

---

[i] "Refraction of Light", n.d., http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/refr.html.