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Flow Visualization
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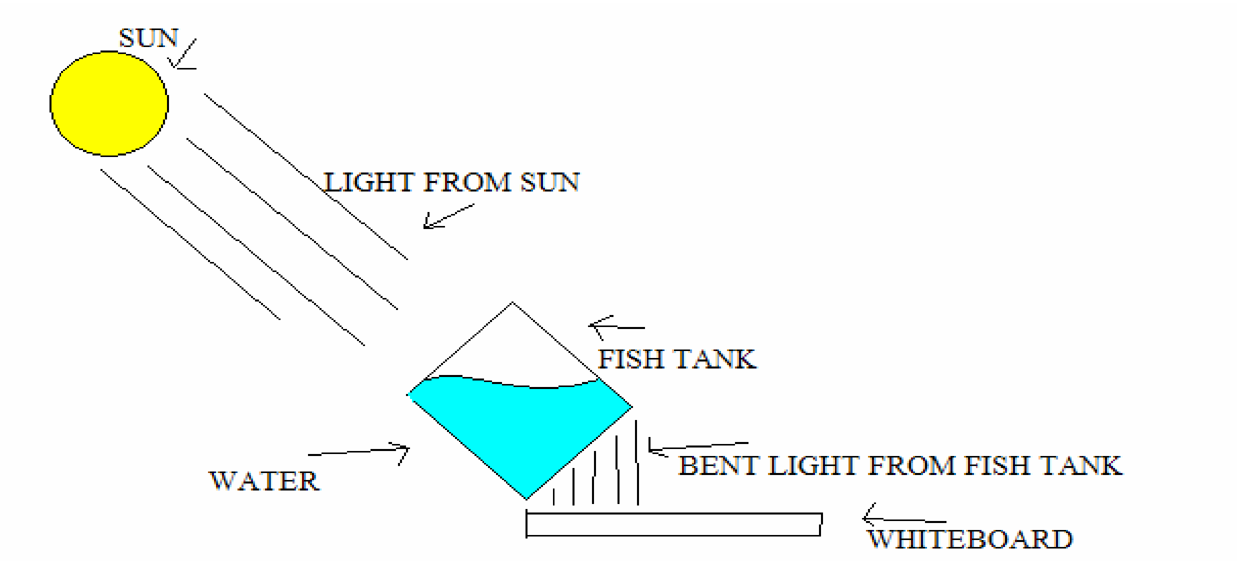
This image comes from work on the second group project, in which we began trying to study Schlieren visualization techniques. However, we had difficulties with the setup, and we decided that we would have more confidence in a Schlieren image if we refined our technique and used it for a different project. But, our group was still interested in the concept of using light-bending to study flow phenomena, and so we decided to move to a shadowgraph setup. Using the shadowgraph technique, we wanted to study a variety of flow patterns; turbulent flow from a propeller, standing waves formed from motion of the tank, vortices created by a magnetic mixer, and stratified mixing coming from different density fluids. Some of these worked better than others, but I actually owe my final image to an unplanned event. During our experiment we were outside to make use of the sun's parallel light, and a ladybug landed in our fish tank full of water. I took a picture of the lady bug on the surface of the water, and of the pattern that it created in the water with the shadowgraph method. What this produced was a very clear image of surface tension effects that resulted from the ladybug staying motionless on top of the water, and what that looked like when visualized by the shadowgraph method.

What the shadowgraph technique is visualizing in my image is the effect of surface tension in water resisting an impingement by a ladybug. Surface tension in water comes from the Van der Waal's force—intermolecular forces induced by the polar nature of water molecules. Normally, these intermolecular forces cancel out because they surround each other, but on the free surface of water, there are Van der Waal's forces on the bottom and the side but not the top. Thus, when an object impinges on the free surface of the water, the Van der Waal's forces exert an attraction and keep the water molecules on the free surface from immediately pulling apart and fully separating. The ladybug was about 1cm long by 0.5 m wide, and it was not moving, so time and spatial resolution are self-apparent. To visualize this phenomenon using shadowgraph, our setup consisted of a large rectangular fish tank filled with water, a whiteboard on which to project shadows, and direct light from the sun. Our whole experiment took place on the sidewalk outside of the Durning Lab in the courtyard of the Engineering Center. We held the fish tank on an incline so that it would be roughly perpendicular to the incoming rays from the sun. The reason we did this was so that we could project a bigger and clearer image using the shadowgraph technique on to the whiteboard.



At this time of the year, the sun is very low relative to the horizon in the sky. The index of refraction of the glass in the tank would cause any light coming into a fish tank that was resting on its base to project a very small image area on to the whiteboard. By tilting the tank until it was roughly perpendicular to the sun's rays, we maximized the project shadowgraph area from the surface of the water. This way, light leaving the fish tank would arrive almost perpendicular to the whiteboard, giving us a clear, and more scientifically accurate (without distortion) image to visualize.

The technique that our group used to visualize the various phenomena occurring in water was shadowgraphy. Optical inhomogeneities cause a distortion of a parallel light source, and the correspondingly constructed or destructed light waves result in a shadow with darker and lighter sections. These darker and lighter sections correspond to the fluid phenomenon in the transparent media being witnessed. It is a very useful technique for visualizing fluid flow that can not easily be seen with the naked eye, or in our case, fluid flow that carries too many reflections and optical problems to provide a clear and scientifically useful image. Our water in a fish tank was the medium being used to pass light through, and the various phenomena occurring on its free surface were easily visualized using shadowgraphy. The only lighting we used was bright sunlight in the outdoors.

Both of the images in the composite were taken with a Nikon D50 and a 28-80 mm lens. Each image had the same settings applied which were: exposure time of 1/2000th sec, an f-stop of 5.6, a focal length of 80 mm, a pixel ratio of 3008 on the x-axis by 1855 on the y-axis, and an ISO setting of 400. Editing with Photoshop CS2 was used, and the following was done to each; in the image with the ladybug, the background was desaturated, and the ladybug's colors were brightened and saturated. On the lower image, the contrast was heightened, some extraneous shadows were spot-healed out of the side of the frame, and the colors were slightly desaturated. The size of the field of view in the top image is about 8 cm by 6 cm, and the distance to the object is about 20 cm. The bottom image has a field of view of about 30 cm by 20 cm, and the distance to the object is about 30 cm.

Overall, I am happier with the fluid physics being revealed in this image than any other I have taken to date. The remarkable effect of an insect walking on water due to surface tension is easily visible, and I believe the corresponding shadowgraph of the ripples in water and the blots caused by the surface tension depressions adds to the overall scientific understanding of the image. If I were to improve upon this image, I think that the main thing would be to get a clearer picture of the shadowgraph. They are difficult to get a clear, in-focus picture of, and I think I could have done a bit better. I think this is a very interesting technique, and I'd definitely like to experiment with it more. I'm not sure that I completely fulfilled my intent though—that is, to produce an image that has artistic value irrespective of the fluid physics being shown, but that still possesses good fluid physics. I think the phenomena being witnessed in these photos are very good and interesting, but I don't think that it has the same artistic impact as other pictures I have taken. I think visualizing surface tension effects, especially with insects, has a lot of artistic and scientific possibility, and I would like to explore this phenomena more. Research on the phenomena of insects propelling themselves on the free surface of water has shown that they actually use the surface tension depressions to create drag and shed vortices, and that this force imbalance propels them through water. I think using dye and high speed photography to capture that phenomenon (a replication of an MIT experiment) would be an extremely interesting way to develop this idea further.