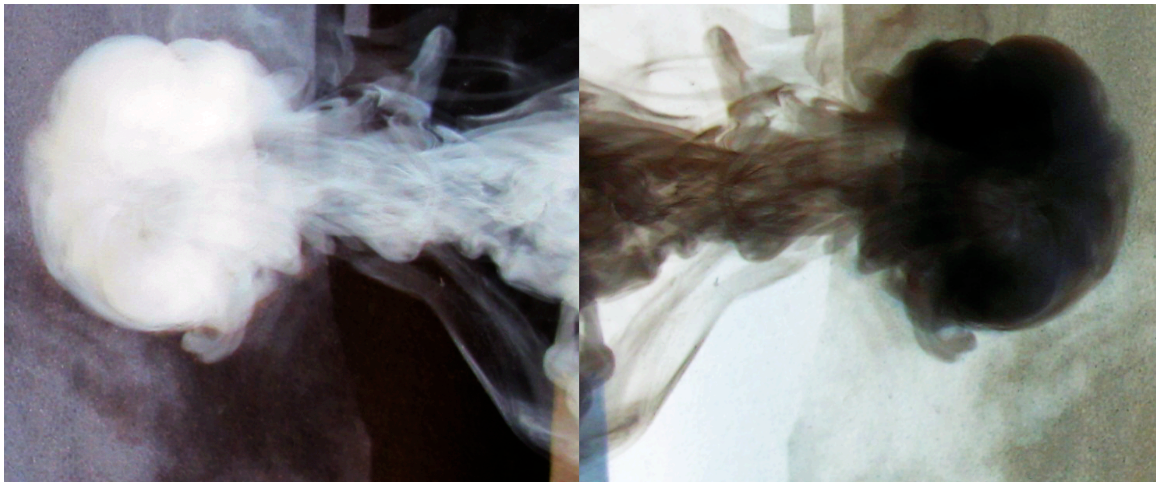

"Smoke Face" 1984 x 1488 pixels : 1/40 s : f4 : ISO 1600

This was the first team assignment that we had for the semester, making it easier to have a good setup. “Smoke Face” was the aftermath of our time creating vortex rings. I have always enjoyed smoke rings, telling smokers to blow them since I was just a young lad. We did not use smoke from harmful products but instead used a fog machine and an apparatus used specifically to generate smoke rings. It was very difficult to get a high quality image of the smoke ring, but I am happy with the outcome

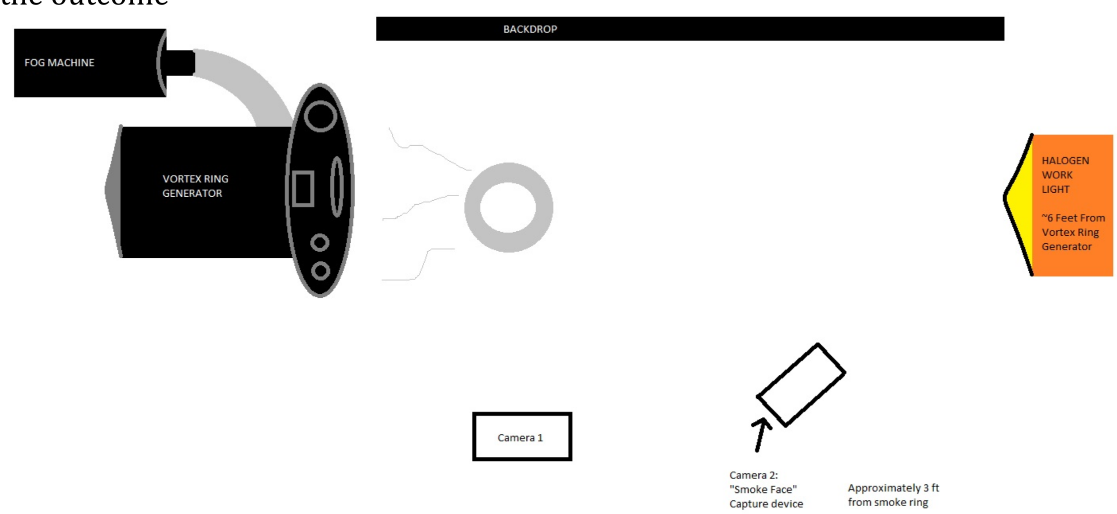

Figure 1: Apparatus

A room in the ITLL was used as the studio for this photo. Initially the smoke rings were being generated by tapping a fog filled box with a hole cut out of it. This was just not getting the results we wanted. When we started searching for a larger box we stumbled upon the vortex ring generator. This can be better seen in Figure 1, but is basically a cylinder that has a rotating plate on one end that allows you to select different shapes, while only shooting smoke from the hole you select. The other end has a piece of plastic that is tightly secured with a large hose clamp. You tap on this plastic when fog fills the cylinder creating the vortex ring through whichever shape you selected. Fog enters in through a small length of duct material that fits over the fog machine. The rest of the setup included the backdrop, a fuzzy black blanket; a halogen work light placed 6 feet from the vortex ring generator, and our cameras placed roughly 3 feet from the subject.

"Smoke Face" was shot using a Canon PowerShot SX230 HS using a shutter speed of 1/40, an f-value of 4 and an ISO of 1600. It has been edited quite a bit from the original image, which can be viewed at the very end of this report. Originally I was drawn to this particular image by the shadow of the smoke ring. I think it shows a lot more detail of the physics that are happening than the actual smoke ring. Photoshop CS5 was used to do the editing and started with just a simple crop. I then adjusted the curves to bring out more contrast in the bright white smoke cloud. The image was then inverted, which was not supposed to be permanent initially. I liked the detail in the inverted image, but also in the non-inverted as well. Both were included in the final image, as mirror opposites, to bring more than one perspective in to play. I then used the clone stamp tool in order to eliminate some hotspots created by the fuzzy blanket backdrop. After completion I spotted a face, as we humans like to do, and hence "Smoke Face" was born.

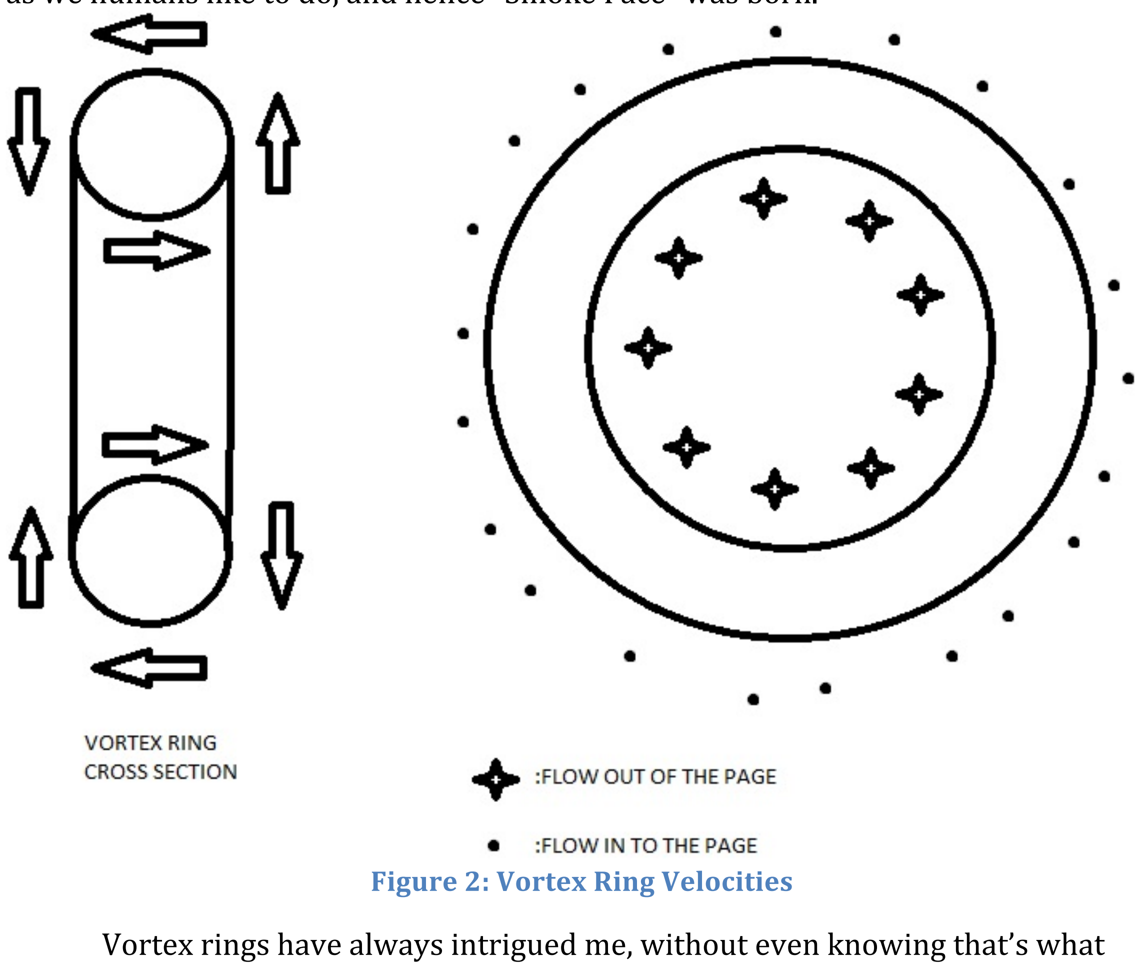

Figure 2: Vortex Ring Velocities

Vortex rings have always intrigued me, without even knowing that's what they were called or the physics behind them. Rings are formed when drag on the fluid creates an imbalance of velocities upon exiting the orifice[1]. Fluid exiting the middle of the orifice moves at a higher velocity than the fluid exiting along the wall. When the fluid enters the stationary medium, in this case air, this difference in velocities creates a circular flow, vortex, which is revolved around the orifice it originated from. The flow is now a ring of vortices, which can be better visualized in Figure 2. As the ring continues through the medium it remains fairly stable. This is due to the vortices within the ring. Most of the smoke remains trapped in the spinning flow created by the vortex ring.

This photo was created using the burst mode setting on the camera. It took multiple pictures, from which we can use to determine the speed of the vortex ring at this instant. By knowing that the camera took 8 pictures a second we can look at how far the ring moved in that 1/8 of a second. Using the square hole as a reference I estimated that the ring moved roughly 4 inches in between the two photos. This leads to a rough estimate of 32 inches per second. Knowing the diameter of the orifice to be 3 inches, and the kinematic viscosity of air we can determine a rough idea of what the Reynolds number is in this situation.

$$Re = \frac{u * D}{V} = \frac{32 * 3}{.0234} = 4102$$

This is ideal for vortex ring formation as a Reynolds number greater than 6 is required for vortex ring formation[2]. We can also determine that the flow is turbulent with a Reynolds number greater than 2000. It may be in a transitional stage, but based off the image itself I would definitely classify it as turbulent.

From the velocity calculated, 32 in/s, I can also determine if my image was time resolved. A simple calculation using the velocity and shutter speed, 1/40 s, can determine that while the shutter was open the subject moved 4/5 of an inch. Ideally it would be better if a higher shutter speed could have been used, but we already had a high ISO and increasing the shutter speed would have produced an image so dark it would not have been usable. We can also determine if we enough resolution to clearly see small details. The image is roughly 1000 pixels wide, ½ of "Smoke Face" and is approximately 8 inches in length, or 125 pixels/inch. The smallest detail in the photo is roughly 1/16 of an inch or roughly 8 pixels assigned to our smallest detail. This picture is special resolved, but not in time.

All in all, I was very happy with the way this image turned out but there are things I would recommend to others trying to capture images of vortex rings. Choose a good clean black backdrop, the one we chose was fuzzy and created some bad hotspots that had to be dealt with in editing. The depth of the smoke ring creates problems with creating a nice focus. I feel like more lighting will create more shadows within the smoke ring, bringing out more detail. I would love to go back and shoot one smoke ring propagating with the high-speed camera. I think that having it in high-speed would really accentuate the flow phenomenon that we were trying to capture in a still image, as well as amplify very small details you would never see in real time or in a still.

REFERENCES:

[1] "Ring-shaped Vortices." *CAELESTIA: A Research Initiative for Unidentified Aerial Phenomena*. Web. 20 Mar. 2012. <http://www.caelestia.be/ringvortex.html>.

[2] Harrison, Tyler, Chris Ostoich, and Chris Kuhn. "Vortex Rings." *Flow Visualization*. University of Colorado, 2006. Web. 20 Mar. 2012. <http://www.colorado.edu/MCEN/flowvis/galleries/2006/assignment3/Kuhn.pdf>