https://vimeo.com/147649268

Fun with a Vortex

Teams 3

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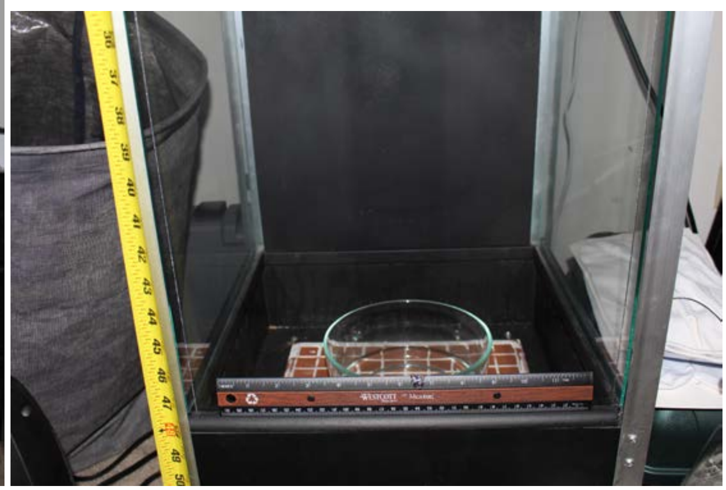
For the third team project, I again wanted to work with dry ice fog as my visualization technique. However unlike with the static environment of the Get Wet project, I really wanted to get an image of a tornado. I have always marveled in the beauty of a vortex, be it a dirt devil on a play ground or a full scale F-5 tornado. With the use of a piece of equipment borrowed from Dr. Scott Kittelman, I was able to achieve my goal of visualizing a three dimensional vortex formation. I had intended to take a still image and use that for my project but I found that photographing what I was seeing was next to impossible. I had no choice but to move towards video and I used my DSLR camera's video function to achieve this.

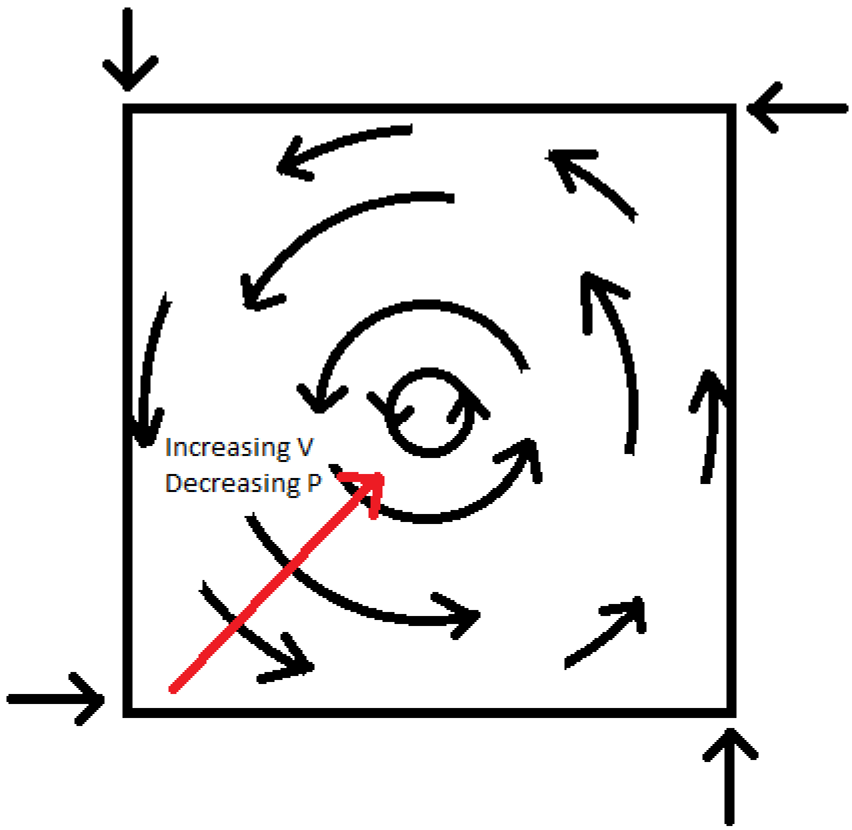



Above you can see the apparatus that I used in the creation of my video. This was a rectangular box 16 inches a side and 30 inches tall. On top of this was a 24 inch, 5 inch diameter, chimney with a computer fan attached to the top. On the base you have a set of leveling feet to allow for precision adjustment and originally there is a hole through the bottom. The box is constructed with a wooden base, 4 piece of 90 degree aluminum, and a wooden top with the chimney and sockets for four light bulbs. In the base box, a series of 10 holes about 3/4" diameter are on both sides. Between the top and bottom boxes glass panels are used as shielding but they allow for a gap between the corners and the glass panels. This gap is what gives the air a starting vorticity and it allows for the vortex formation. The gaps at the corners were half an inch in width and another half inch in depth. The fan on the top of the chimney allowed for three different fan speeds using a controller built into the system and was run off a 12V DC power supply. The controller allows for the varying of the flow rate between 21CFM on low (1200 RPM), 28CFM at medium (1600 RPM), and 38CFM on high (2200 RPM).

After the fan of the chamber is turned on, the pressure in the chamber decreases, with the lowest pressure in the center of the box. This in turn draws in air through the vents in the side and the holes in along the side of the base. By forcing the air to enter at the sides of the apparatus, we are able force the air to rotate as a rigid body with zero vorticity [1]. The tornado is an example of an irrotational vortex. As the packet of air rotates around the chamber and moves towards the center low pressure area, its rotational velocity increases. As the packet nears the center of the chamber, its vertical velocity increases as well causing it to rise out of the chamber. Based off the volumetric flow rate and exit chimney diameter, we can also determine the velocity of the air as it leaves the chamber.

$$\frac{Q}{A} = V$$

For the video, only the fast and slow fan speeds were used. This means that the exit velocity when the fan was going its slowest was .075 m/s and on the fastest setting, the velocity was 1.35 m/s.



Dry ice fog was used as the "dye" to visualize the flow. Inside of the water bowl, the dry ice sublimates at a temperature of -109. 3°F[2] giving off a bubble of CO_2, upon breaking the surface of the water, this super cooled CO_2 cools the air around it and immediately saturates the air surrounding it, dropping the temperature below its dew point and causing the water vapor in the air to condense into micron sized water droplets[3]. For the lighting, two 60W "Daylight" 5000K LED light bulbs were used in the two sockets closest to the front pane of glass. This provided a nice white coloring and gave me a crisp clean image. The entire setup was done in my bedroom with no lights on. I had a real issue dealing with reflections coming off the glass because the room is so small.

As stated in the introduction, video was the photographic technique used to capture the vortex. This was done with Canon EOS SL-1 DSLR. The sensitivity was set at 1600 ISO, 4.0 aperture and a shutter speed of 1/60 of a second. The video was shot in HD 1080p 1920x1080 resolution. The camera was placed 5 feet away from the box and the image was cropped to a field of view of 14 inches wide and 24 inches tall. This removed all the unnecessary components and meant that the camera could not see the lights. The video was edited from 5 separate clips using Adobe Premiere Elements. The only post processing done besides cropping was the slightly increase contrast and decrease brightness.

Overall I am very happy with the end result. I spent a lot of time tweaking the video and reshooting to get the effects and images I wanted. I like that the video reveals the fragility and beauty in the live cycles of a vortex. There is a very pleasant aesthetic to how a vortex forms or how it falls when its source of low pressure gets removed. The video was not an attempt to reveal fluid physics and as such and is lacking in that regard, but I felt doing so would take away from overall feel of the video. I was able to find surprisingly little information about the formation of these smaller not atmospheric vortexes and it's something I feel is lacking in this report.

[1] Classical Fluids, "Circulation and Turbulence" Chapter 3 Retrieved From http://maxwell.ucdavis.edu/~cole/phy9b/notes/fluids_ch3.pdf

[2] Cengel, Y., and Boles, M., 2011, "Thermodynamics: An Engineering Approach", McGraw Hill, pp. 912 Appendix 1

[3] Cengel, Y., and Boles, M., 2011, "Thermodynamics: An Engineering Approach", McGraw Hill, pp. 731-755, Chap. 14