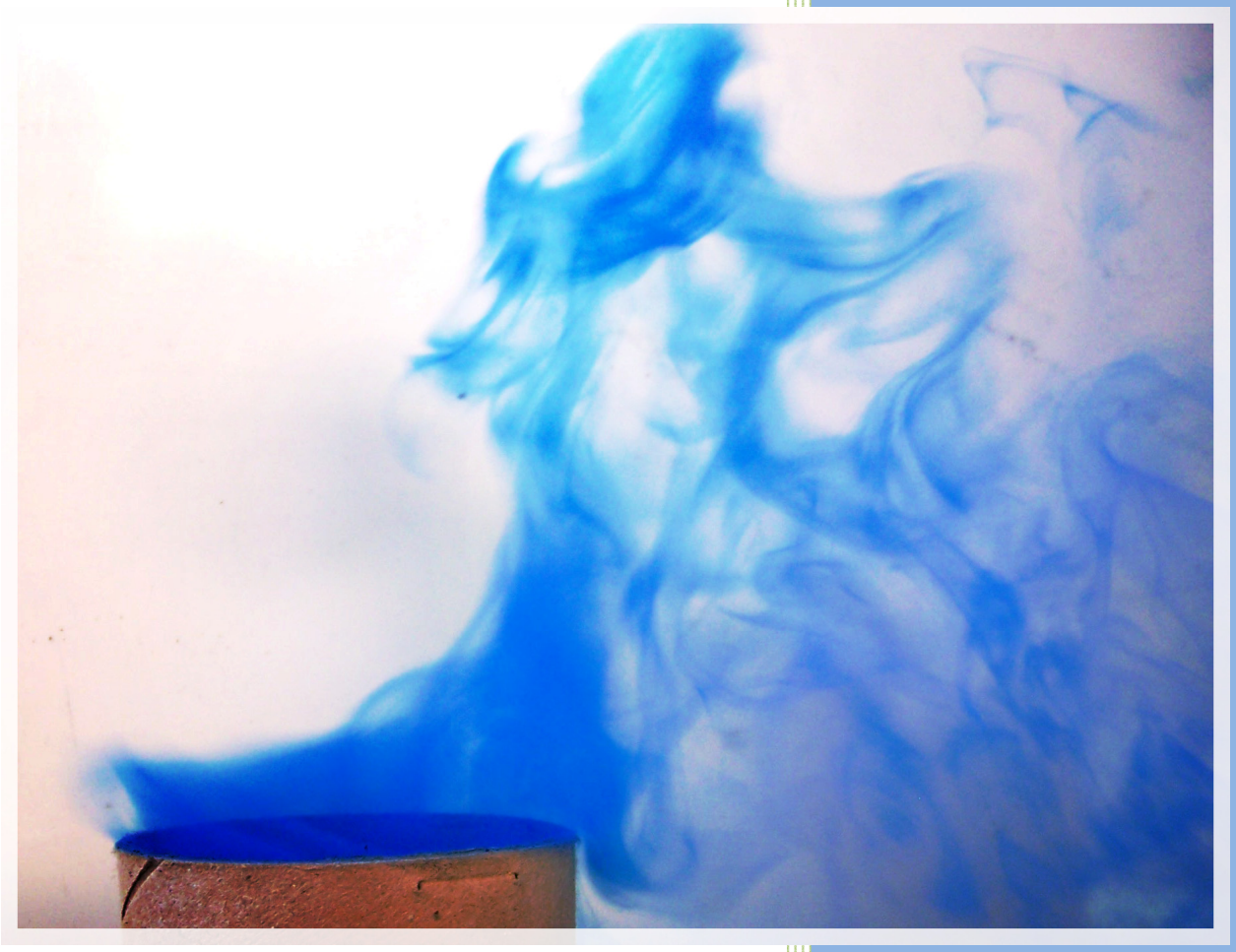
Smoke Phenomena in the Wind



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Flow Visualization

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Context

This image is one of the images submitted for the second group project for the course flow visualization at the University of Colorado-Boulder. The purpose of this assignment is to meet with our group members, explore different flow ideas, and capture three images of unique flow phenomena. The group aspect of the project encourages communication and team work. However, for this particular group project the group members met separately because of spring break and difficulties of meeting during that time. The idea behind this image is capturing smoke blowing in the wind. This image gives the perception of a smokestack and how the smoke is uniquely shaped as it blows away from the cylinder. The apparatus used to visualize this flow was the inside of a paper towel roll and a blue smoke bomb. Originally, all sorts of smoke bombs of different colors were used with and without the cylinder and dozens of pictures were taken. Of all the images taken, this was chosen because of the flow phenomena, the colors, and the overall beauty of the image. The picture was cropped to show the desired aspect of the image and processed in Photoshop to enhance the contrast and colors.

Apparatus

The apparatus used to create the image was very simple. The inside of a paper towel roll was cut in half and placed over a commercially available smoke bomb. The smoke bomb was lit and began smoking through the paper towel roll. The image shown displays the smoke as it is coming out of the top of the roll and interacting with a steady breeze. The wind was blowing approximately 10-15 mph on the day this picture was taken. The background of the image is a large white poster board that was brought outside. It is important to do this experiment outside because the smoke is very strong smelling and will leave colored stains on anything that it touches. Dozens of pictures were taken of the phenomena shown in the final image. This image was chosen amongst the others because it shows a unique blend of colors and displays the most interesting rolls and movement of the smoke in the wind.

Flow Phenomena

The phenomenon of smoke has been observed for millennia. Long ago, people used smoke signals to communicate from great distances away from each other. In the present day, one of the most important aspects of smoke is pollution and air quality control. A great deal of research goes into modeling air quality around plants and pollution emitting facilities.[1] This image is attempting to simulate how smoke moves as it leaves the top of a smokestack. The blue smoke helps to visualize exactly how all of the smoke particles move and what shapes the smoke takes. It also allows the viewer to visualize how quickly smoke moves through the air and how quickly is diffuses and dissipates.

One phenomenon that smoke experiences in the wind is the Kelvin-Helmholtz instability. The Kelvin-Helmholtz instability is caused by 'velocity shears between two media'.[2] It is caused by the centrifugal force which leads to a change in pressure from a curvature in one of the media. The result is more visible curves in one of the media. In the image shown, one can see some minor curves in the smoke which go on to create other curves in the smoke farther away from the cylinder. Although this phenomenon is very minor in this illustration it still displays the basic aspects.

The Kelvin Helmholtz instability has been widely studied and mathematical models exist that predict its formation.[3] With smoke blowing in the wind, pressure differences exist causing the formation of vortices. These vortices induce an instability which causes the vortices to continue to propagate. The mathematical model describing this phenomenon deals with pressures, velocities, and densities.

The Navier-Stokes equations can be used to mathematically calculate the movement of smoke through the atmosphere. The Navier-Stokes equations can be applied to any fluid system with movement in an incompressible system.[4] With the use of the Navier-Stokes equations and mathematical modeling tools, the movement of smoke in the air can be accurately predicted.

Visualization Technique

The technique used here is the application of a dyed smoke bomb to create a dramatic coloring effect. The smoke is more easily seen when dye is used as opposed to using uncolored smoke. The paper towel roll was placed on top of the smoke bomb in order to concentrate the smoke in one area instead of letting it diffuse out into the entire atmosphere. The final result is a dramatic blue colored smoke that is focused into one area, and a picture can be taken of the fluid phenomena. The lighting used was ambient light from being outside in the late afternoon. I was underneath an outside patio covering that provided shade to the area the picture was taken. The flash of the camera was not necessary with the amount of ambient light in the area. There is no distracting source of light in this image. The background was chosen because it wouldn't cause any reflection of light and take away from the flow phenomena.

Photographic Technique

The original image was much larger than the final cropped image. The original image was zoomed in far enough to only see the top of the paper towel roll and all of the exiting smoke. The most interesting and colorful section of the image was cropped to produce this final image. The camera was approximately two feet away from the smoke at the time the picture was taken.

The image was taken with a digital *Kodak Z612* digital camera. The original image size is 2832 pixels wide x 2128 pixels high while the cropped image size is 1860 pixels wide x 1419 pixels high. The camera exposure specifications for the photograph were; an aperture equal to 2.8, the shutter speed at 1/50 s, and ISO speed setting at 80. The focal length was 5.85 mm. The flash of the camera did not fire. The image was processed in Photoshop. The only changes made to the image in Photoshop were cropping the desired section of the image and adjusting the contrast using the 'Curves' and 'Levels' features. The darker colors were made slightly darker and the lighter colors were made slightly brighter.

Revelations

The image reveals the unpredictable effects that the atmosphere has on smoke. Each of the pictures taken with this set up was different in its own way. They all displayed the smoke's movement and had similar qualities, but only this one showed the unique blend of colors along with very interesting fluid dynamics. The intent of the image was fulfilled. Once the set up was created and many pictures were

taken, the general idea of how the smoke would look in the wind was known. This image shows how the smoke was moving better than any of the others. One aspect that could be improved is the clarity of the smoke. I had to use my father's camera because I was at home over spring break and forgot my higher quality camera in Boulder. If a higher quality camera were used to capture the smoke, the image may be slightly clearer and more focused. To develop this idea further, one may experiment with a higher quality camera, more images, and different smoke colors. Changing any one of these things may result in a very different image that may be more effective.

References

[1] McMillan, W.W. et al. An observational and modeling strategy to investigate the impact of remote sources on local air quality: A Houston, Texas, case study from the Second Texas Air Quality Study. Journal of Geophysical Research Atmospheres. 2010.

[2] Kelvin-Helmholtz Instability. Online. http://casa.colorado.edu/~danforth/science/cloudshock/node5.html.

[3] Kelvin Helmholtz Instability. Online. http://hmf.enseeiht.fr/travaux/CD0001/travaux/optmfn/hi/01pa/hyb72/kh/kh_theo.htm.

[4] Dobashi, Yoshinori. Simulation of Various Natural Phenomena based on Computational Fluid Dynamics. Hokkaido University.