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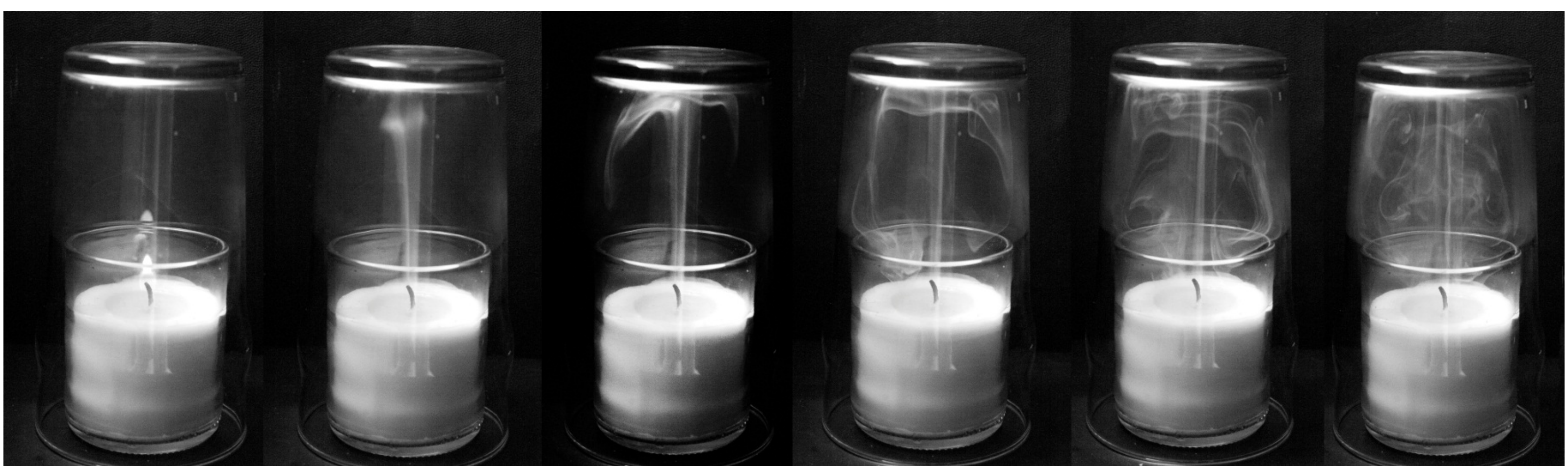
FLOW VISUALIZATION

MCEN 4151

“Get Wet”



The image was my submission for our initial assignment “get wet” in the course Flow Visualization. Capturing and creating the image allowed us to practice our photography and photo editing skills, along with a practice of physics and flow creation. The image I created, which is a few photos next to each other, is a quick time lapse of smoke rising from an extinguished candle underneath a clear glass. As the candle initially snuffs itself out by burning through the available oxygen, the plume of smoke can be seen rising vertically. The hot smoke is much more buoyant than the cool air around it, and as it rises creates a small current in the glass. When the warm smoke reaches the bottom of the glass (top of its enclosure), it is forced to the edges by the rising smoke below it. It cools as momentum carries it in contact with the glass. It eventually becomes neutrally or less buoyant, and at this time gets re-introduced to the rising smoke from the center. The rising current lifts the cooler smoke, and as the cooler smoke resists, vortexes are created and can be seen in the images.

The smoke in the image is demonstrating buoyant forces, as warm, less dense, gas rises in cooler, denser, gas.

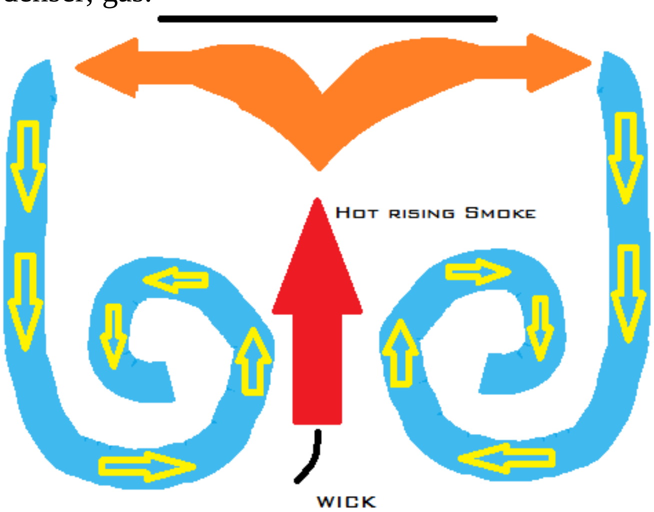


Figure 1 Flow temperature diagram

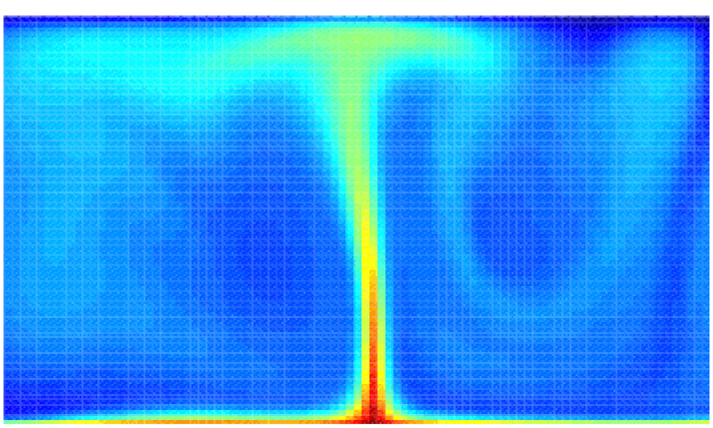


Figure 2 Heat Map

Figure 1 and 2 are flow and temperature profiles for the image on the right of the experiment taking place. If you look closely in image three you can see a vortex that has formed just above and to the left of the wick. The event that is occurring is best described as “Natural Convection” which is caused by temperature differences in fluids which affect the density, which changes the relative buoyancy. As stated above, the denser heavier fluid (marked in blue) falls downwards, as the less dense and relatively lighter fluid rises. The larger the temperature difference in fluids is the larger the relative buoyant force, which means a greater speed in the rising or falling fluid.

Solving for the Reynolds number in this scenario it yields a value under 2000, which is indicative of a laminar flow. This makes sense based on what we are seeing, which is a uniform stream of smoke. Another important value to consider is the Rayleigh number, which indicates the strength of convection within a fluid.

$$\mathrm{Re} = \frac{\rho \mathbf{v} L}{\mu} = \frac{\mathbf{v} L}{\nu} \qquad \mathrm{Ra}_x = \mathrm{Gr}_x \mathrm{Pr} = \frac{g\beta}{\nu\alpha}(T_s - T_\infty)x^3$$

In this scenario the large Rayleigh number (10^6 to 10^8) indicates that the convection forces are the primary forces involved in moving the smoke.

The visualization technique used to view the phenomenon is the same technique used to create the phenomenon, the smoke. Smoke is the visual aide in this scenario, allow the human eye to see the convection occurring, without having to monitor temperature and pressure profiles. To properly capture and present the scenario, I had to take several pictures over the course of a short period of time starting just before the candle extinguished up until the smoke in the glass had become completely turbulent and/or of uniform temperature. I had to create a 4 sided black box so outside light pollution and reflections on the glass were not an issue. Initially I attempted to create a lighting scenario that made the glass appear invisible or as if it was not there. But after several attempts I realized that this was not going to be possible and also was not necessary. I used a single overhead light source, approximately 60 watts of mostly white light, with some ambient light allowed to come in from the front. With all this in place, I lit a small candle and place a small clear glass over the lit candle. The candle quickly consumed all the available oxygen in the glass and extinguished itself. I began capturing photos from the time when the flame dimmed, as it smoked, and until the smoke in the glass completely displaced the original contents and it was no longer rising or falling.

When I photographed the smoke, I was using a relatively close up lens EF50mm f/1.8. I had little depth that I wanted to capture, as the background was all black and I only desired to capture the smoke from the candle. With the close up lens, I positioned the camera about 2 feet from the object, towards the end of the focal length of the lens; the focal length was 50.0mm. I utilized a digital Canon EOS 5D to capture the images. I used a relatively high ISO for the camera, with a 1/50 of a sec shutter speed which yielded non blurry results of the rising smoke. The rest of the photo data is shown in the image.

Make:	Canon
Model:	Canon EOS 5D
Date Time:	2/2/2013 – 2:17:54 PM
Shutter Speed:	1/50 sec
Exposure Program:	Manual
F-Stop:	f/6.3
Aperture Value:	f/6.3
Max Aperture Value:	f/1.8
ISO Speed Ratings:	1250
Focal Length:	50.0 mm
Lens:	EF50mm f/1.8
Flash:	Did not fire

Pixel Dimension X:	2912
Y:	4368
Orientation:	
Resolution X:	240
Y:	240
Resolution Unit:	Inch

I used photo shop only to enhance the natural image in order to exemplify the smoke and convection phenomenon. I altered the image contrast slightly to make the white/grey smoke more visible against the dark background. I also changed the color scale in order to make the image more than 90% black and white. With a small adjustment to the exposer value, I made the image slightly brighter as well, again making the smoke more visible.

I believe the image is a great example of natural convection, and the “time lapse” presentation leaves little to the imagination and would serve well as a learning tool. I personally like how “quiet” and subtle the image is, as an example, it would be a very peaceful wall mural. Because though it would draw attention, it would not be overwhelming and it would not make the space it resides in too loud. In the future I would like to improve my “photo booth”, because with less pollution and more light control, the smoke could be made much more visible, and the glass less focal in the image. I believe I fulfilled the intent of the image, and I enjoy it.

Works Cited

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