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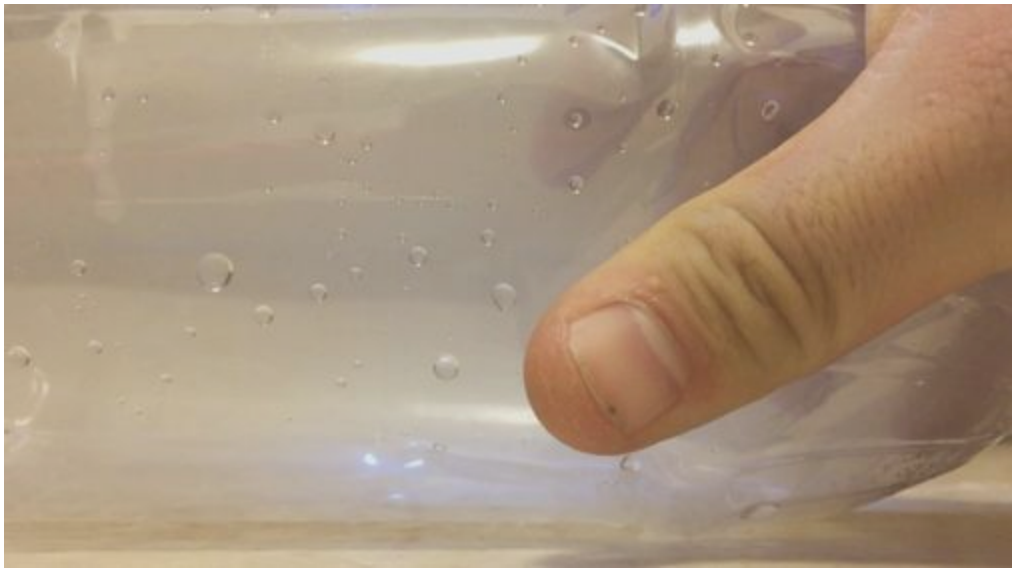
Final Assignment Report

John Zeldes

Flow Visualization
Professor Hertzberg
University of Colorado, Boulder



Motivation

This video was created for the final assignment in a course called Flow Visualization, taught by Dr. Jean Hertzberg at The University of Colorado, Boulder. The ultimate goal of this work was to create an aesthetically pleasing video of a dynamic fluid. A fluid is any substance that continuously deforms under shear stress [1]. Dynamic implies that the fluid is moving, as opposed to being still. The video was taken and edited by John Zeldes. Rachel Grosskrueger was influential in the decision to create a fluid flow involving phase changes of water. Initially, the project was to involve supercooling of purified water. This would allow the water to freeze instantly if poured over an ice cube. Due to poor handling of the supercooled water, the liquid turned to a solid before leaving the bottle. In an effort to relate the two projects, another non-intuitive phase change of water was investigated. This report details a video in which a cloud is formed inside a bottle. The key mechanism to creating this phenomenon is squeezing the bottle. This temporarily increases the pressure, causing the vapor to liquify when the pressure decreases as the bottle is released. Such a cloud can be seen on the cover of the report. The top image shows the bottle without a cloud, and the bottom image shows the bottle with a cloud.

Background

The apparatus used to create the vapor cloud can be seen in figure 1 below.

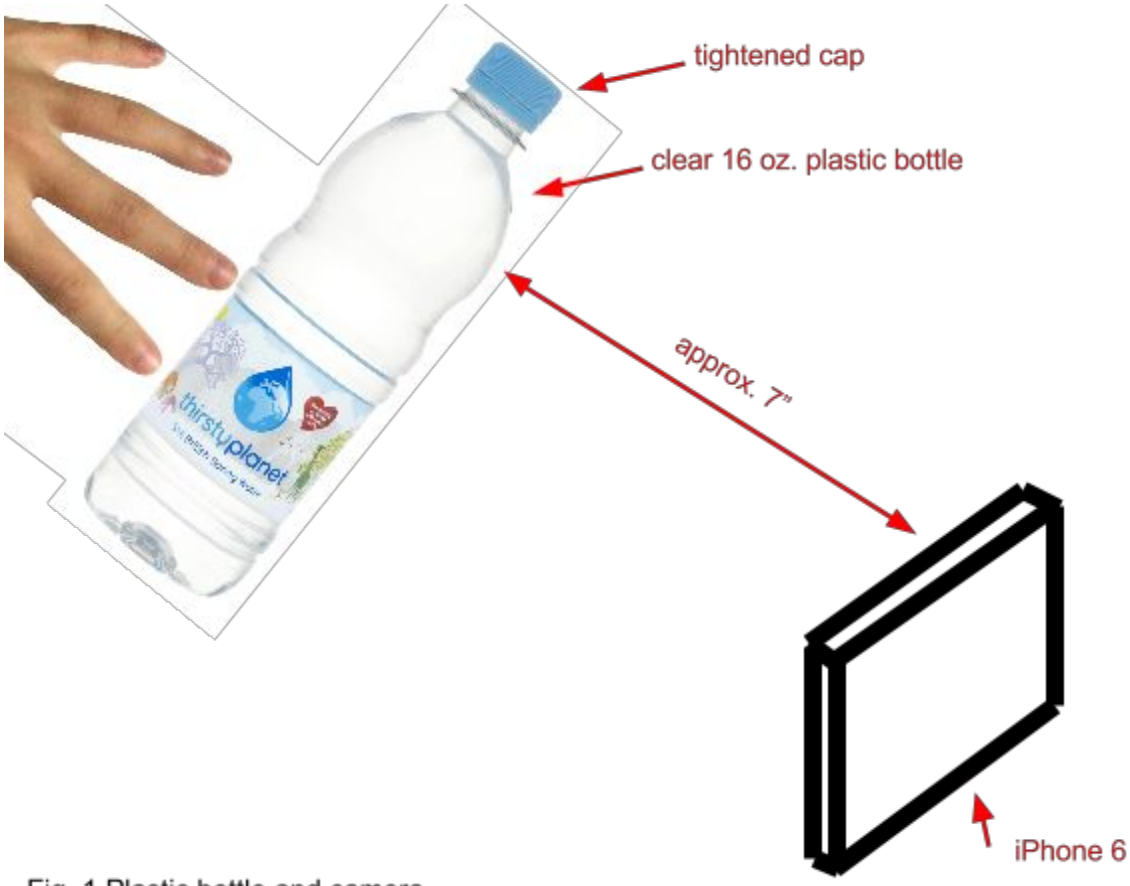


Fig. 1 Plastic bottle and camera

The cloud was produced using unpurified water, a clear 16 oz. plastic bottle, and smoke particles captured from combustion of paper. Another aspect of creating the cloud is the squeeze, which was made by pressing on the bottle by hand. The flow in the video occurs in a phase change instigated by the brief change in pressure. In this case, water is condensing to form a cloud. The cloud evenly fills the bottle, which is slightly over 16 oz. in volume and is a cylinder of typical water bottle proportions.

As seen in the video, the flow is changing with time. Why? It is obvious that the force causing the flow comes from the squeezing of the hand, but how does this force cause the phase change? When the bottle is squeezed, some air is pushed out as the container changes shape. Upon the bottle being released, the container attempts to take its original shape, which creates low pressure in the bottle. This low pressure causes cooling of the water vapor in the bottle. As the water vapor cools, it condenses on small dust particles in the air [2]. This is how the force from squeezing the bottle creates the cloud. The phenomenon lasts approximately six seconds with this size bottle and a strong squeeze.

Visualization Technique

There were no particles or other fluids (i.e. smoke, dye, flakes) mixed with the water in order to *visualize* the flow. However, smoke was a factor in creating the cloud itself, as described previously. The key aspect to visualizing the flow in the case is light. The water is clear, but distorts and reflects light, enabling the flow to be visible. The video was produced indoors in a corner of a well lit room. The room had overhead lights with incandescent bulbs. In addition, a bright white LED was suspended above the bottle. The background was smooth and light brown in color.

It was discovered that in order to achieve good visualization technique, it is important to choose a container wisely, as the reflection it causes will limit your ability to vary the background and lighting. The bright LED's reflection is visible on the bottle's surface, and the background does not give great contrast against the cloud. This experiment was attempted with different lighting and a black background, but the cloud was not visible until so much light was on the subject that the bottle's reflection ruined the shot.

Photographic Technique

An iPhone 6 camera was used to film this experiment. The iPhone's lens has a (35 mm equivalent) focal length of 29 mm [3]. The video was shot with the phone in the horizontal position in order to capture as much of the bottle as possible. The height of the field of view was then determined by the diameter of the bottle. This led to a field of view of approximately three inches by six inches. In order to achieve this size field of view without using digital zoom, the

lens was about four inches from the object. The user has some control over the “brightness” of the iPhone video, but the exposure settings are mostly automatic. Focus is also automatic. The final video is 1920 x 1080 pixels. The film was edited using iMovie. The footage was not altered, just trimmed with the addition of a title and some transitions.

Conclusion

The image reveals the relationship between condensation and pressure. I like the physics being shown in the film, as the experiment is fun and unique. I also like how easy and repeatable the it is. Unfortunately, the visual technique was the weakest part of the project. In order to improve in the future, I would try the experiment outside in bright sun with as black and white scale in the background for better contrast. The film could have benefited from cropping the thumb out of sight, but I wanted the viewer to understand what was occurring. If the experiment is to developed further, adding food coloring to the water may make the cloud more visible. In large, the intent was fulfilled, as the film shows a cloud visible after the bottle is released. The physics shown are not drastic, so it is difficult to capture the subtle formation of a cloud.

URL

https://vimeo.com/147644901

References

[1] Munson, Bruce R., and Donald F. Young. "Introduction." *Fundamentals of Fluid Mechanics*. 6th ed. Don Fowley, 2009. 3. Print.

[2] "Cloud In A Bottle." *Physics.org*. Institute of Physics. Web. 14 Dec. 2015. <http://www.physics.org/interact/physics-to-go/cloud-in-a-bottle/>.

[3] Sorrel, Charlie. "IPhone 6 vs. Regular Camera … Fight!" *Vantage*. Medium.com. Web. 15 Dec. 2015. <https://medium.com/vantage/iphone-6-vs-regular-camera-fight-ed7429d20b84#.77g9uy6ta>.