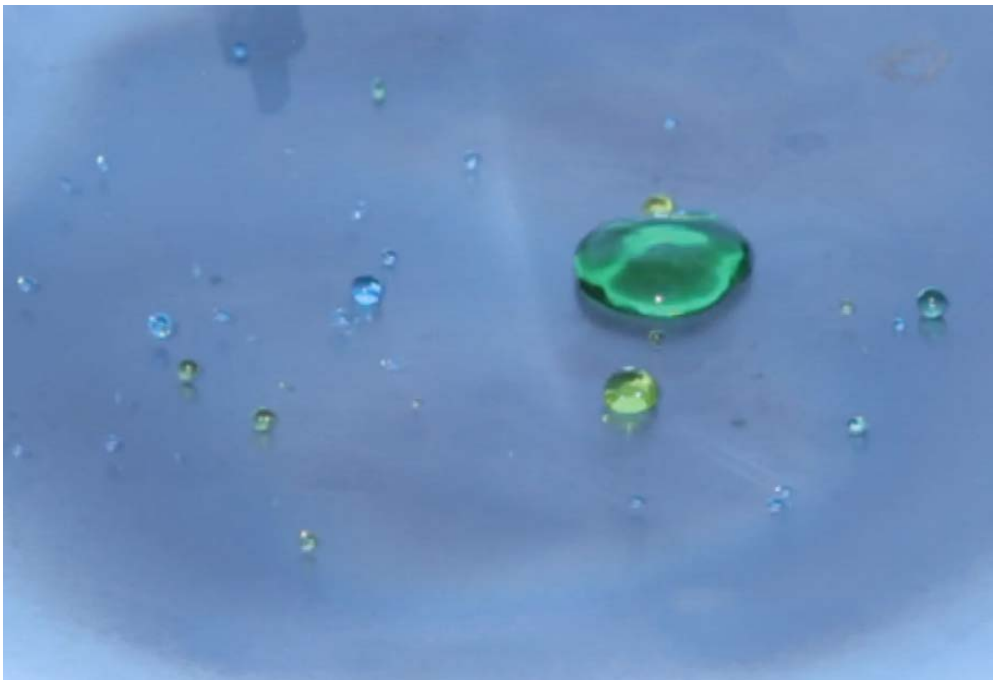
First Team Project:

Leidenfrost Effect



Video link: http://vimeo.com/88233185

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Purpose

For this video, the purpose was to create flow visualization as our first team project. My team members were Ryan Coyle, Philip Latiff, and Michael McCormack. We set out to create fluid phenomena using a hot plate and a pizza pan. The initial idea was to create an explosion by combining water and oil and to capture that on a high speed camera. After attempting alterations to the large amount of light necessary for the high speed camera, we decided to move the experiment outdoors into the sunshine. However, the clouds gave us very small windows to work with, and the high speed camera was taking too much time to store footage taken. So, we decided to move forward with regular camera and video equipment and begin our experiment. We cranked the hot plate up all of the way, placed the pizza pan on, and began dropping water droplets through a syringe on the pan. We were mesmerized by the effect and decided to proceed.

Procedure/ Visualization Technique

The setup for this experiment was outside in the bright sun. As seen in figure 1, the experimental apparatus included a hot plate set to maximum heat with a 13 inch diameter aluminum pizza pan on top of it. A Canon Rebel T2I was placed on a tripod about four feet from the setup. Four syringes were filled with water and food dye mixtures. There was one filled with red, yellow, blue, and green blends. Droplets from the syringe were then pushed out onto the pan.

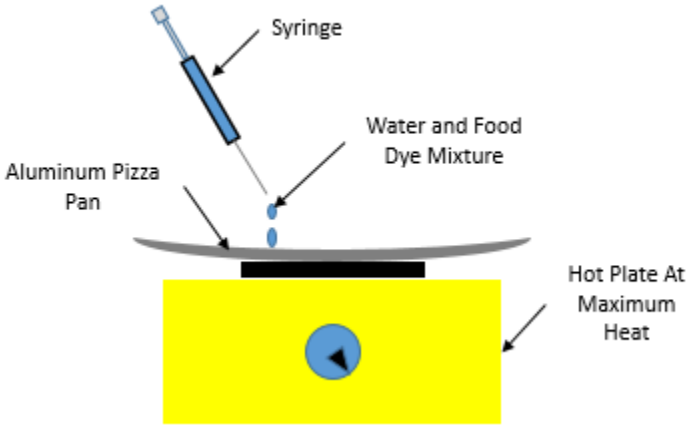

Figure 1: Flow visualization appartus

These droplets began spinning around on the surface combining into one amoeba-like shape as seen in figure 2. We liked the effect that was turning up, so the group decided to experiment with making different colors with combinations of droplets. In the first part of the video, the green water was made with blue and green food dyed water, and in the last part the purple water was made with blue and red food dyed water. After getting extensive footage of this amoeba-creation effect, we experimented with using the syringes to drop vegetable oil at room temperature onto the floating water droplets. As seen in figure 3 on the

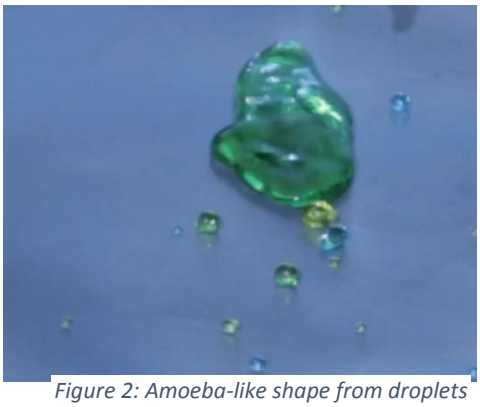

Figure 2: Amoeba-like shape from droplets combining

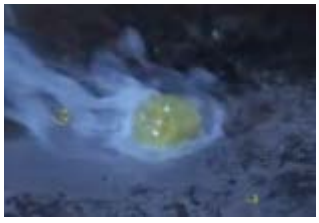

Figure 3: Droplets with vegetable oil added

previous page, the droplets became filled with bubbles and created a lot of steam. I did not include this effect in my video, because the steam covered up a lot of what was going on and looked fairly messy.

Physics Involved

The fluid phenomena that underlies this experiment is the Leidenfrost effect. The Leidenfrost effect occurs when a liquid is on an object that is significantly higher than its boiling point (Leidenfrost point).[i] The Leidenfrost point of water is estimated to be around 220 °C(~425 ° F).[ii] When this Leidenfrost point is met, a vaporous layer forms under the liquid, propelling that liquid up, as shown in figure 4. This causes the liquid to float on the surface, evaporating very slowly, causing the effect seen in the video initiated the direction of movement to always stray towards the middle, making it easier for the individual droplets to create the amoeba-shape. This was caused by the slope of the pizza pan.

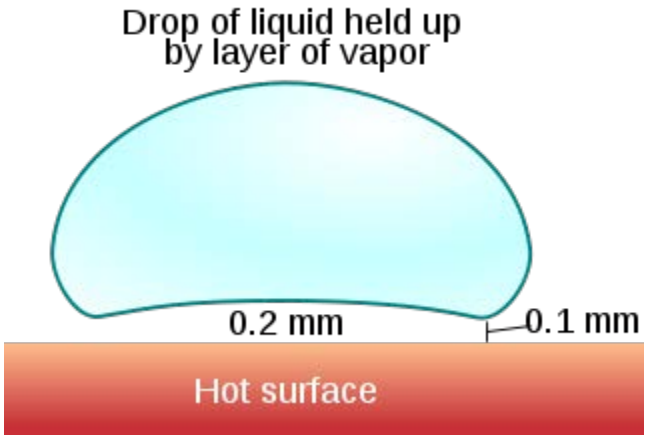

Figure 4: Diagram demonstrating Leidenfrost Effect (from http://en.wikipedia.org/wiki/Leidenfrost_effect)

Another interesting effect was also present in our specific experiment due to the pizza pan's diameter being approximately twice as large as the diameter of the hot plate itself. This combined with the aluminum alloy pan's inability to conduct heat well throughout resulted in a non-uniform temperature. A large temperature gradient radiated out from the middle of the pan as seen in figure 5. The middle area (red region) touching the hot plate was at the Leidenfrost point, so the water floated around. If it happened to float away and get into the region not quite at the Leidenfrost point (green region), the water would quickly boil and evaporate. If the water drifted into the region not at the boiling point (blue region), it would sit there and do nothing until it was cleaned off. Interesting enough, the black region on the very outside of the pan was cool enough to touch without getting burned.

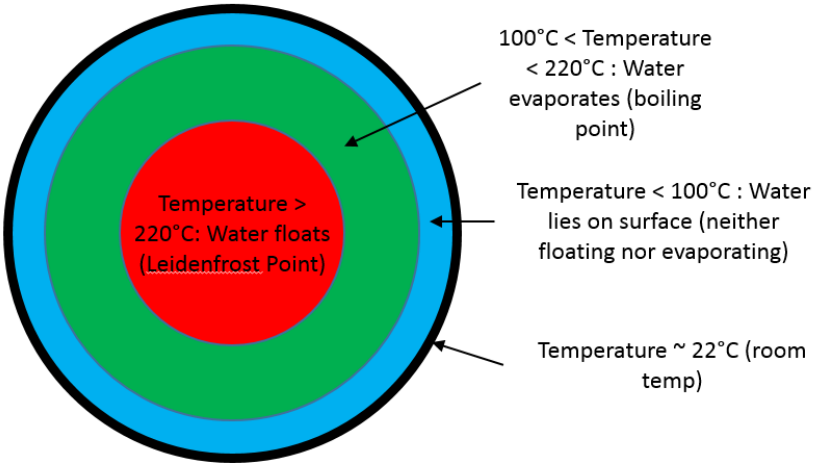

Figure 5: Water behavior at each temperature gradient

Photographic Technique

The video was taken in the bright sunshine, with a Canon Rebel T2I setup on a tripod approximately four feet away from the setup. The field of view was 7.5 x 10 inches and the ISO was set to 100. The f stop of the camera was at 8and the focal length was set to 135 mm. The video width is 1280 x 720 and was shot at 60 fps. In the last scene of the video, the footage is slowed down to 30 fps. VideoPad Video Editor Professional was used to select and put together the specific scenes used in the video.

Conclusion

Having the temperature gradient throughout the pan was unintended, but revealed much more physics then simply having the entire pan at the Leidenfrost point. This caused a combination of dancing droplets and slight explosions at the boiling point, breaking up the droplets. The way the droplets floated around was very mesmerizing, but my video might have been a little long. I might have been able to capture the same effect with a minute long video. If I were to repeat a similar experiment, I may try to replicate the Leidenfrost Maze.[iii] However, my intentions for the video were accomplished and art was made.

Bibliography

[i] http://en.wikipedia.org/wiki/Leidenfrost_effect
[ii] http://www.math.upatras.gr/~weele/weelerecentresearch_Leidenfrost.htm

[iii] http://www.itsokaytobesmart.com/post/60388319391/leidenfrost-maze