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IV 3
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Leidenfrost Effect

Introduction

The objective of this image is to capture the Leidenfrost effect in action. This effect causes a fluid to be cushioned by vapor when exposed to a hot surface (higher than the boiling point). This cushion of vapor leads to the fluid evaporating much slower than if the surface were at a cooler temperature. I would like to thank Anders, Sander, and Abdullah for assisting with this visualization.

Apparatus

The apparatus for this image was quite simple in practice. A sketch of the setup is provided below.

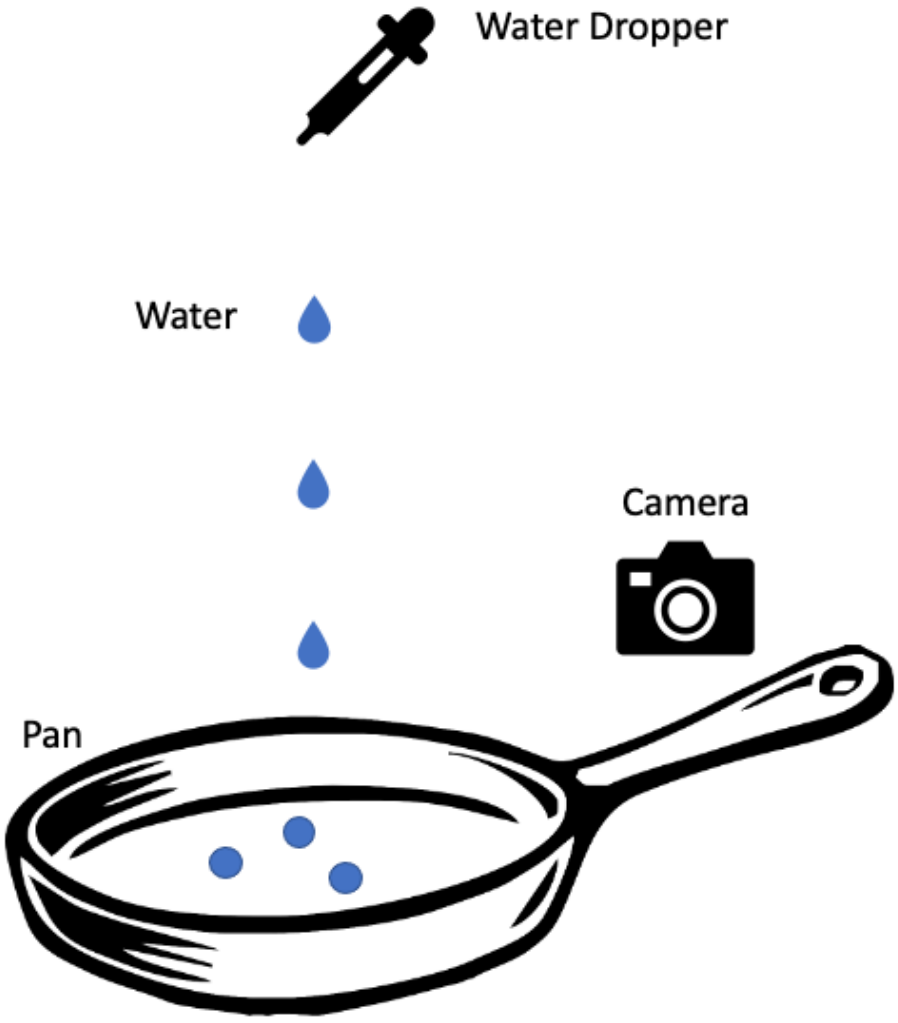

Figure 1: Apparatus

Dyed liquid was siphoned into a dropper which was held above the pan at a height of 3 feet. The water was then dripped onto the hot pan (kept at 400 degrees Fahrenheit) and the Leidenfrost effect was visualized.

Flow Physics

The primary fluid phenomena seen in this image is called the Leidenfrost effect. This is characterized by a sharp decrease in evaporation rate once the temperature of the pan is high enough. This temperature in question is called the Leidenfrost temperature. For a drop of water on a hot pan, this temperature is roughly 380 degrees Fahrenhiet [1]. Above this temperature, the evaporation rate is so fast that when a droplet is released over the plate, the droplet levitates over its own vapor. Because the vapor under the droplet acts as a thermal insulator, the evaporation rate drops drastically [2].

The flow in this video can also be characterized by the Weber number, a dimensionless number that relates the inertial force to the surface tension force [3].

$$We = \frac{\rho v^2}{\sigma}$$

Where ρ is density, v is velocity, and σ is the surface tension. In the case of stationary drops of water, the Weber number is zero because the velocity is zero, indicating surface tension dominates. However, for the falling droplets, the velocity is roughly 7-8 m/s, so the Weber number for these is 680555, indicating the inertial forces are dominant. We can see both of these cases in the video.

Visualization Technique

The technique for this image is very simplistic and easily repeatable. As described previously, the water was slowly dripped onto a hot pan in order to visualize the Leidenfrost effect. This water was dyed with Wilton food coloring until a desired color was achieved. For my video, I used a combination of yellow and red in the same dropper to produce a changing color effect.

The lighting of this shot was done with many different light sources. We had a hood light above the stove, 5 overhead lights as an ambient source, and a lamp to add a little more ambient light. Camera flash was not used when taking this photograph.

Photographic Technique

This video was taken using an iPhone X with a 4mm lens. The properties for my final image are tabulated below.

Image Property	Value
FPS	240.51

Focal Length	4 mm
ISO	N/A
Aperture	N/A
Pixels	1920 x 1080

Table 1: Photograph Specifications

The lens itself was 8 inches from the liquid in the pan in order to capture the fluid phenomenon and avoid as many distracting elements in the peripheral as possible. The field of view of the original video is 66 degrees horizontally and 46 degrees vertically.

The ISO setting and aperture were not recorded in the metadata for this video, but iPhone automatically chooses the appropriate settings for the current lighting. This video was taken in using the ‘slow-mo’ feature of iPhone to get the greatest frame rate possible.

Finally, the video was cropped in iMovie to remove the distracting elements at the top of the original video. Music was also added (“Stepping Out Medium”) from iMovie’s built in library, and a title was added to the beginning of the video.

Conclusion

This video shows the Leidenfrost effect in action, along with some very interesting physics with what I assume is lower drag on the water droplets. The droplets hover and move very swiftly across the surface of the pan which is very entertaining to watch. I really like the color gradient as the video progresses as well, I think it adds a nice touch. The one thing I am not as satisfied with is the focus of the image, as I think the droplets could be clearer and sharper. My nicer camera does not have video capability, so the iPhone X camera had to be substituted. There is a lot less control with an iPhone camera which may have reduced the quality of the video.

References

[1] *Engineers Edge*. 2022. 2 November 2022.
[2] Sobac, Benjamin and Pierre Colinet. "Leidenfrost Drops." *Science Direct* (2015).
[3] Engineering ToolBox, (2004). *Weber Number*. [online] Available at: https://www.engineeringtoolbox.com/weber-number-d_583.html