Get Wet Report

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Context and Purpose

This image captures the striking physical phenomenon that occurs when cold water droplets are introduced to a skillet heated well above water's boiling point. The intent of the experiment was to visualize the Leidenfrost effect, where droplets of liquid levitate and move erratically on a cushion of their own vapor rather than boiling away instantly. I chose this setup because it is a simple but visually compelling way to observe complex heat transfer and fluid dynamics in everyday life.

The purpose of the image was to reveal both the chaotic beauty and underlying physics of droplets "dancing" across the skillet surface. False starts occurred when the skillet was not heated sufficiently; in these cases the droplets sizzled and evaporated rapidly without levitation. Once the skillet temperature exceeded roughly 200 °C, however, the Leidenfrost effect became stable and visually clear, producing the final image shown.

Flow Apparatus and Physics

The experimental setup was minimal: a cast-iron skillet of diameter approximately 25 cm was placed on an electric stovetop and heated for ~10 minutes until the surface was scalding hot. Cold tap water at room temperature (~20 °C) was released from about 5–10 cm above the skillet surface. Droplet size varied for an average size of 2–3 mm.

Upon contact, the base of each droplet vaporized instantly, generating a thin layer of steam that prevented the rest of the droplet from directly touching the surface. This vapor cushion both insulated the droplet from rapid evaporation and propelled it across the skillet as the steam escaped unevenly beneath it. The result was the visual "dancing" or skittering motion characteristic of the Leidenfrost effect.

From a fluid mechanics perspective, the forces acting on the droplet include:

- **Vapor pressure** generated by rapid boiling at the base
- **Surface tension** maintaining droplet cohesion

- **Drag forces** from air and vapor beneath the droplet
- **Gravity**, acting downward, balanced by the vapor cushion's upward pressure

To characterize the flow regime, the Reynolds number was estimated. Taking a droplet diameter $D \approx 0.003\,\mathrm{m}$, a typical droplet speed $U \approx 0.1\,\mathrm{m/s}$ across the skillet, and the kinematic viscosity of water vapor at high temperature $\nu \approx 1.34 \times 10^{-5}\,\mathrm{m^2/s}$:

$$Re = \frac{UD}{\nu} = \frac{(0.1\,\mathrm{m/s})(0.003\,\mathrm{m})}{1.34 \times 10^{-5}\,\mathrm{m^2/s}} \approx 22$$

This low Reynolds number indicates that the vapor flow beneath the droplet is laminar, though the droplet's chaotic motion arises from unstable vapor release and asymmetry rather than turbulent mixing. The Leidenfrost temperature threshold for water is typically around 200–210 °C, which aligns with the skillet conditions.

Visualization Technique

The visualization relied on direct observation of the droplet motion against the dark matte background of the skillet. The material used was cold tap water; no dyes or additives were introduced. Environmental conditions were standard indoor lighting, with overhead light illuminating the skillet. Because the surface of the cast iron skillet is dark and reflective, it provided contrast to make the bright water droplets visible.

No special tracers were needed, as the droplet itself served as the flow marker. The vapor layer was not directly visible, but its effect was inferred from the levitation and erratic skittering of the droplets.

Photographic Technique

The image was captured using a Canon Rebel T3i DSLR equipped with a Canon EF 50mm f/1.8 STM prime lens. The camera was positioned approximately 30 cm above the skillet at a downward angle. The field of view spanned roughly the 25 cm diameter of the skillet, with the camera focusing on the center region where droplets first landed.

- **Lens:** Canon EF 50mm f/1.8 STM
- **Image resolution:** 5184 × 3456 px (native resolution)
- **Exposure settings:** Aperture f/4, shutter speed 1/80 s, ISO 3200

- **Other settings:** White balance set manually, metering mode: pattern, exposure program: manual
- **Image processing:** Cropping for focus on droplets, contrast boost, sharpening to bring out the droplets' edges

The 50mm focal length provided a natural, undistorted perspective while allowing me to fill the frame with the skillet surface. Using an aperture of f/4 balanced light sensitivity with enough depth of field to keep multiple droplets sharp. The ISO of 3200 compensated for the relatively fast shutter speed (1/80 s), ensuring proper exposure under indoor lighting conditions. These settings allowed me to capture both the discrete Leidenfrost droplets and the chaotic boiling region in the same frame, highlighting the contrast between the two phenomena.

Reflection on the Image

The final image reveals the elegance of the Leidenfrost effect: droplets appear suspended and alive, darting unpredictably as they ride cushions of vapor. The physics are effectively demonstrated and it is clear the droplets are not boiling away instantly but instead persisting for several seconds on the hot surface.

An interesting detail occurs in the left side of the image, where the water appears to simply be boiling rather than exhibiting the Leidenfrost effect. This is likely due to the larger amount of water present in that region: instead of forming discrete droplets, the water spread out into a thin layer. Without sufficient isolation, the vapor layer could not form uniformly, and the liquid boiled off in direct contact with the skillet surface. This provides a useful contrast between ordinary boiling and the Leidenfrost state within a single frame.

I am pleased with the clarity of the droplets and the contrast provided by the skillet background. However, one limitation is that the vapor layer itself remains invisible, leaving only indirect evidence of the phenomenon. A higher-speed camera or side-lighting with a laser sheet could potentially reveal more detail of the vapor dynamics.

This experiment fulfilled my intent of documenting the Leidenfrost effect in an everyday kitchen setting. For future work, I would like to compare how droplet size influences the stability of levitation, or to explore different liquids such as oil or alcohol, which have different boiling points and surface tensions. These variations could extend the study of this visually captivating and physically rich phenomenon.

References

- Leidenfrost, J.G. (1756). *A Tract About Some Qualities of Common Water*.

- Biance, A.L., Clanet, C., & Quéré, D. (2003). Leidenfrost drops. *Physics of Fluids*, 15(6), 1632–1637.

- Quéré, D. (2013). Leidenfrost dynamics. *Annual Review of Fluid Mechanics*, 45, 197–215.