# Showcasing the Rayleigh-Bénard Convection

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Team Second Project Report
11/10/23

## Introduction:

For our second team project, my team and I decided to replicate the captivating fluid phenomenon known as Rayleigh-Bénard convection and film it shown in this video. Using simple materials like canola oil, mica powder, a baking tin, and a hot plate, our primary goal was to work together to see how the oil and mica powder would behave when heated. While the initial video didn't capture all the captivating cell patterns we hoped for, the experience itself unfolded as an engaging experiment that has room for improvement. As we carefully heated the canola oil and observed its interaction with the introduced mica powder, the project became a valuable learning experience, refining our teamwork skills and understanding more about the fluid dynamics behind this phenomenon. Over the course of the experiment, we witnessed the fluid's ever-changing shapes and flows, offering glimpses into the subtle yet captivating world of thermal convection. The blend between heat and fluidity emerged as a captivating art form, with the mica powder responding to the convective currents, creating little patterns that offered glimpses of the beautiful phenomenon. I want to thank my teammates—Greg Kornguth, Stella Meillon, and Austin Sommars—for their contributions, making this fluid experiment a collaborative success that provided us with a scientific background of the phenomenon.

## Rayleigh-Bénard Convection Explained:

In regards to fluid dynamics, I will explain the captivating world of Rayleigh-Bénard convection, focusing on the interplay between heat and fluid motion. Our experimental setup involved a shallow baking tin filled with canola oil and a uniform sprinkling of micah powder.

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The dimensions of the tin were approximately 10.6 x 6 x 2.8 in and we added about 0.65 inches in height of the canola oil. Then we mixed gunpowder silver, brown, and gold mica powder into the oil. The tin was carefully placed on a hot plate, initiating a controlled heating process at about 180 degrees Celsius. As the canola oil absorbed the heat, the fluid underwent little transformations, giving rise to small bubble-like patterns that are very close to the characteristic of Rayleigh-Bénard convection. The heat-driven motion within the fluid resulted in the formation of convection cells, resembling a feedback control loop of warm and cool oil currents. As the oil heats, the oil on the bottom of the dish becomes less dense causing them to float to the surface because of their buoyancy. Once the oil reaches the surface, it begins to spread out because the surface tension of the warm oil is less than the cool oil. This difference in temperature causes the oil to spread and create a loop. (Moore, youtube.com)

Our team could not fully replicate the phenomenon because we did not consider the Rayleigh number. We did not know that whether the Bénard cell forms all depends on the dimensionless number called the Rayleigh Number (of the oil). The following is the Rayleigh Number:

$$Ra = \frac{g\beta}{\nu\alpha}(T_b - T_u)L^3$$

Here, "g" is the acceleration due to gravity, "β" is the thermal expansion coefficient of the oil, "ν" is the viscosity of the oil, "α" is the thermal conductivity of the oil, "$T_b$" is the temperature at the bottom, "$T_u$" represents the temperature at the upper part, and "$L$" is the height of the oil column. When the Rayleigh Number reaches 1708, the cells form. The following figure shows a simple schematic of the lab setup:

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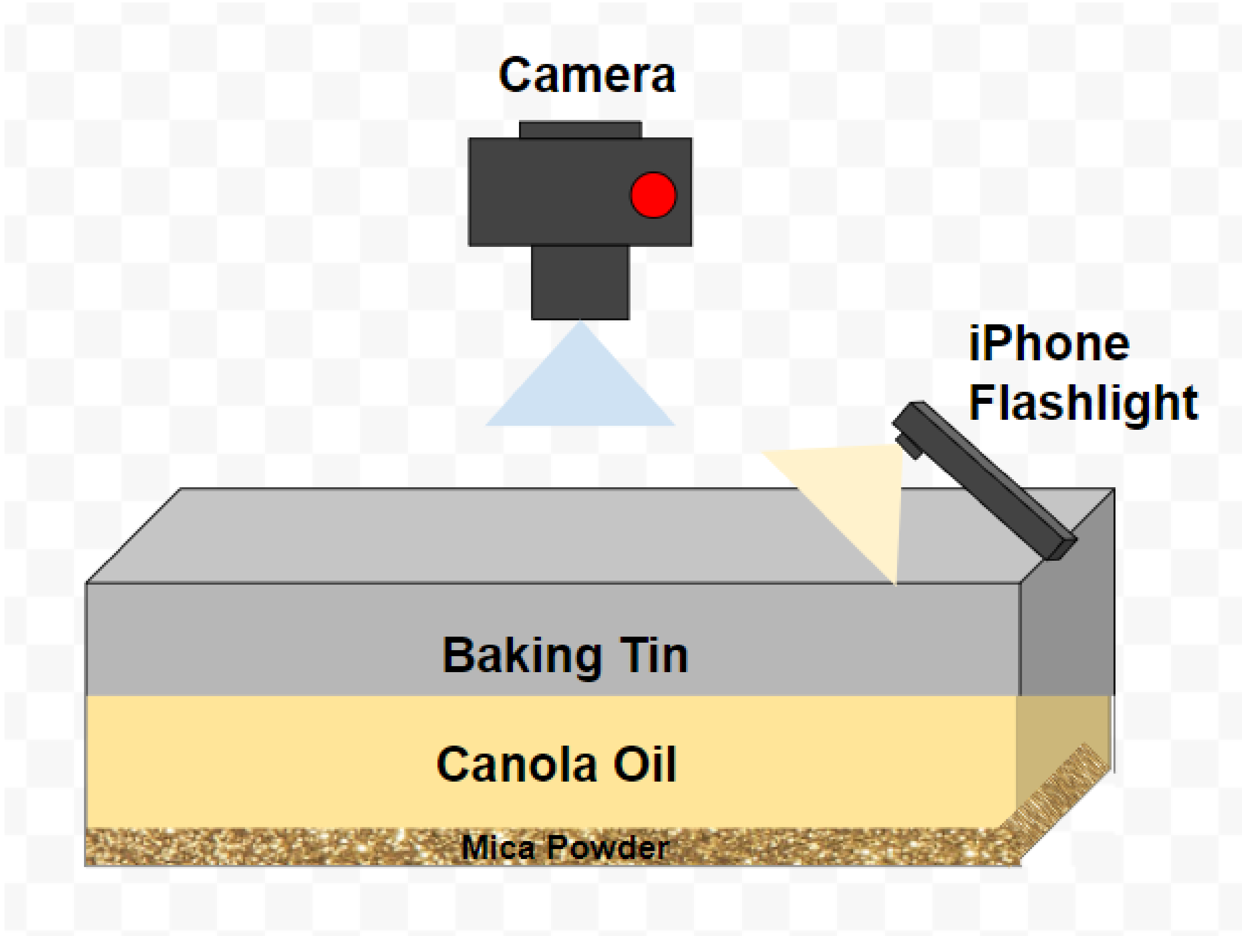


***Figure 1:*** *Schematic of the experiment setup including the camera setup*

## Visualization Technique:

For the experimental setup for the project, we encountered challenges with the initial approach, primarily related to the Rayleigh number of the oil and the interference of the flashlight's light source off of my teammate's phone. We filmed this phenomenon in the basement of the ITLL which has standard fluorescent light. When I was filming, my body shadow made it hard to see the mica powder interacting with the oil. I asked my teammates to position to my right slightly angled towards the baking tin. However, this adjustment introduced a challenge— the light source became evident in the reflection captured on video. Recognizing the need for improved contrast, we introduced two more different colored powders into the oil. The single-color powder did not offer sufficient contrast to effectively showcase the convection patterns. We conducted multiple takes, combining various mica powder colors to enhance the visual appeal and better highlight the minimal fluid dynamics in the final video I uploaded. We also improvised our initial plan and added droplets of water to see the oil bubble up and move around the mica powder in a mesmerizing way shown in Figure 2. If you look at Figure 1, the schematic shows that my camera was about 6 inches away from the surface of the oil and the iPhone flashlight was right next to the camera.

## Photographic Technique:

My photographic technique was to simply catch the Rayleigh Bénard cells as steadily as possible even though I used my bare hands. I was able to capture y video with a frame size of 1920x1088 pixels with a frame rate of 29.97 frames per second. The distance between my camera lens and the top layer of the oil was approximately 6 inches (15.24 cm). When compiling my video, I used Microsoft Clipchamp to edit the video to showcase what I captured in real-time and at 0.5 playback speed to slowly show the oil bubble up as shown in the figure below.

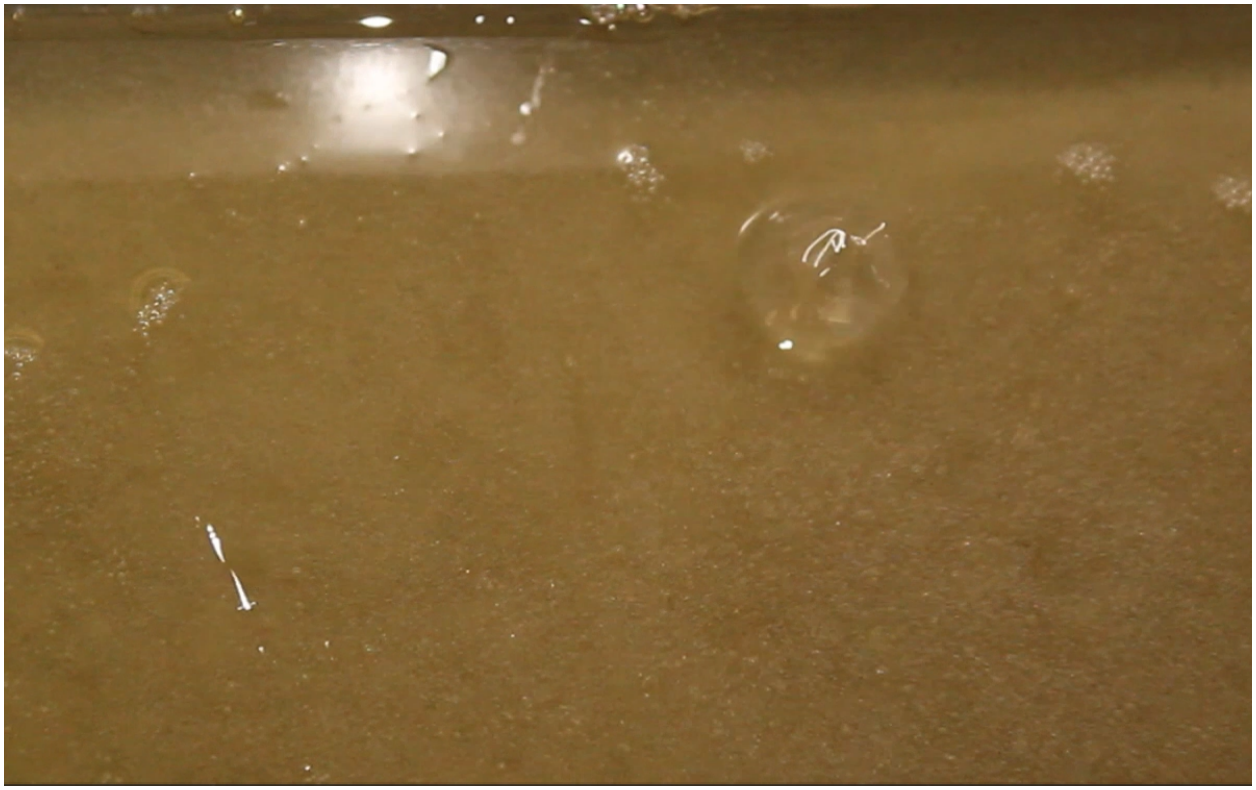

***Figure 2:*** *A screenshot of the moment a big bubble burst when we added droplets of water to the experiment setup showing the mica powder moving around*

## Conclusion:

Overall, our team's attempt to replicate the Rayleigh-Bénard convection unfolded as well improvised, specifically how were set with the challenge to replicate this phenomenon, not be successful about it, then executed multiple iterations until we found a cool interaction between the oil and the mica powder. While our initial attempts faced hurdles related to the viscosity of the oil, reflections from the light source, and insufficient contrast from the mica powder, our adaptability led to my final creation shown in my video. By integrating a teammate's phone flashlight and experimenting with a combination of mica powder colors, we enhanced our visualization techniques and captured a more vivid flow. Reflecting on this experience, we acknowledge the importance of refining methods and equipment for future experiments, such as planning for better oil to use and finding optimal lighting conditions. This project not only deepened our understanding of fluid dynamics but also showed us the importance of adaptability and continuous refinement when experimenting.

## Source:

Moore, N. [NickMoore]. (2023, November 10). Rayleigh–Bénard convection cells [Video]. YouTube. https://www.youtube.com/watch?v=gSTNxS96fRg&ab_channel=NickMoore