# The Fascinating Ferrofluid

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Team First Project 1 Report
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## Introduction:

In the photo that I captured for this first Team First project, I showcased the captivating, stalagmite patterns using a simple apparatus consisting of a large magnet, ferrofluid, and a rod (refer to figure 1). While the idea of working with ferrofluid seemed intriguing, none of us had a clear plan in mind. The primary objective of this assignment was to establish our teamwork dynamics and collectively generate a series of images using our chosen phenomenon. Given this, we thought it was the right moment to explore the potential of ferrofluid and capture its flow visualization. We acquired a very viscous ferrofluid from Professor Hertzberg and its main application is intended for automotive purposes. We embarked on a sequence of experiments and trials, each one bringing us closer to our own final image. Over the span of an hour, we employed various types of magnets to manipulate the fluid, giving rise to diverse shapes and flows, which we documented. In the end, we achieved our goal of learning how to collaborate effectively as a team and execute a successful flow project. I would like to express gratitude to my team members, Greg Kornguth, Stella Meillon, and Austin Sommars, whose contributions were crucial to the success of this experiment.

## Fluid Mechanics Behind the Ferrofluid:

In our experiment with the magnet and ferrofluid, we set up a flow apparatus that involved a metal rod that was ≈ 45 cm in length and a diameter of 1cm. To visualize the flow, we introduced a large magnet that was attached to the bottom of a metal bowl (approximately 10 cm in diameter and 0.5 cm thick) which was smeared with ferrofluid. This ferrofluid had a thick

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viscosity although the manufacturers did not provide the exact value. Our objective was to observe the behavior of the ferrofluid in response to the magnetic field generated by the magnet. We used the rod to dip into the ferrofluid and smear it onto the magnet. The initial state of the ferrofluid showed no noticeable deformation. However, as we brought the rod further away from the magnet, the fluid started having intriguing changes. The ferrofluid started to form distinctive, spiky structures, resembling miniature metallic forests or stalagmites, seemingly defying gravity. The fluid seemed as if it were stretching itself to try to be in contact with the end of the rod. This transformation occurred due to the interaction between the magnetic field and the ferrofluid's magnetic nanoparticles. We noted that as we moved the rod within the boundary of the magnetic field, the ferrofluid formations dynamically adjusted their orientation. Given that this fluid is non-Newtonian, I would say that calculating the Reynolds number (Re) is not necessary.

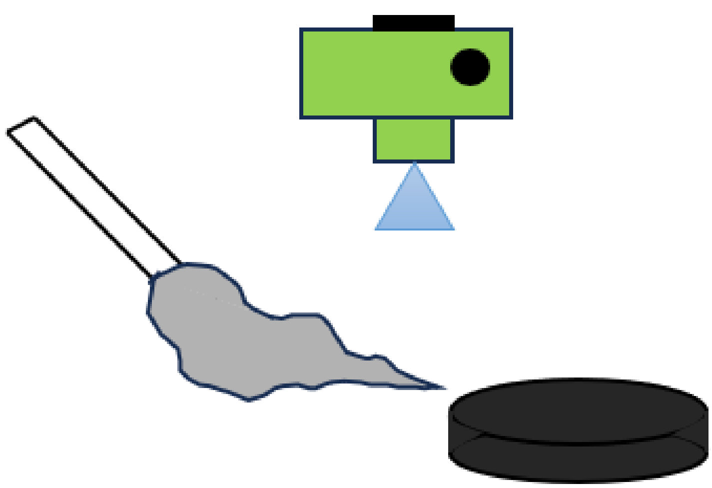

***Figure 1:*** *Schematic of the experiment setup featuring the black magnet, rod with ferrofluid on the end, and camera setup*

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## Visualization Technique:

The initial approach our team had in mind proved unfeasible because of challenges in the viscosity of the ferrofluid and its interaction with the magnets. We relied solely on natural lighting, with the sun positioned just above the flatirons at approximately 4 o'clock in the evening. However, this lighting condition posed issues related to shadows in specific camera angles. Consequently, our experimental setup became quite adaptable as we had to deviate from our initial approach. We conducted multiple iterations, experimenting with various visualization techniques and making use of the magnets available to us. For my photograph, my setup is shown in Figure 1. Our equipment inventory included an assortment of small magnetic materials, a dry-erase board, a ⅜-inch thick acrylic sheet, a substantial aluminum rod, ferrofluid (comprising 10% magnetite and 90% oil and distillates), and magnetorheological fluid.

## Photographic Technique:

A Canon EOS Rebel T6 Digital SLR Camera Kit with EF-S 18-55mm f/3.5-5.6 is II Lens was used to capture this image, taken roughly 6 inches from the magnet. This distance allowed me to easily capture the stalagmite pattern in the frame and in focus without having to zoom as much. Zooming at that close of a distance would make focusing the image quite difficult. The exposure specs included a 1/540 sec. exposure time, ISO-1000, and an f-stop of f/5.6. This exposure time was selected to capture the stalagmite pattern stretching out as far as it can while retaining its shape (reducing the blurriness of the image). The rest of the camera settings were used in order to integrate a beaming natural light into the image. After capturing the image, the CRW file was loaded into Photoshop to boost the contrast, brightness, and sharpness of the image while also altering the color profile to manipulate the light and highlight the individual stalagmites. The dimensions of both the before-edited and after-edited images were 5184 x 3456 pixels which are shown in Figures 2 & 3 below respectively:

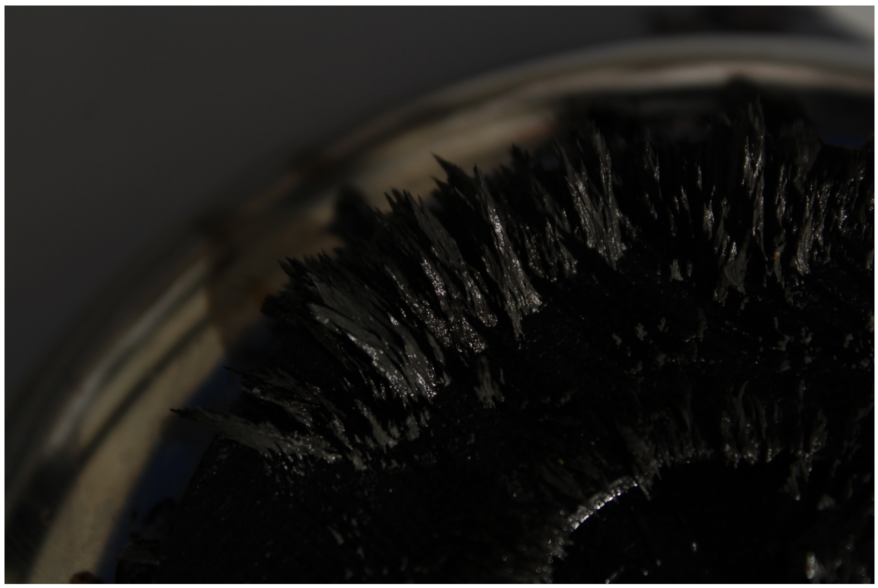

***Figure 2:*** *The original image taken on my camera*

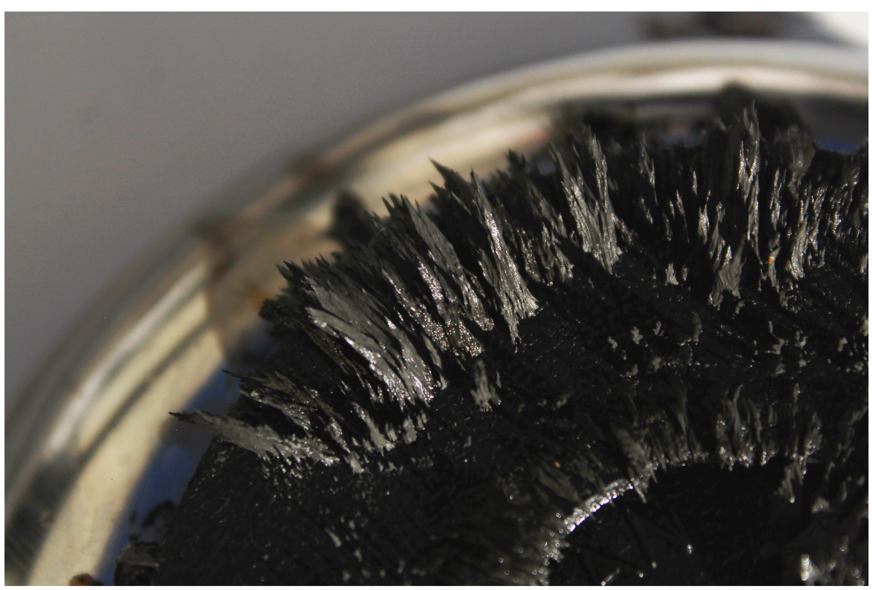

***Figure 3:*** *The final edited image using Photoshop*

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## Conclusion:

Overall, the ferrofluid project presented its own unique set of challenges and opportunities for experimentation. While our initial idea encountered setbacks in obtaining the famous porcupine shape produced when a magnet was present and dealing with lighting issues, we improvised and captured our own perspective of a well-taken photograph. Through multiple iterations with various visualization techniques, we gained valuable insights into the complex and viscous force that governs the ferrofluid's behavior when presented with magnets. As we reflect on our experience, we recognize the importance of fine-tuning our methods and equipment for future experiments. For example, we could have planned to take the photos when there was a better angle of the sun aiming at our subject. This would ease the photography process and allow us to capture precise and captivating visualizations. With additional resources, we may be able to delve deeper into the world of ferrofluids, perhaps capturing their mesmerizing behavior in ultra-slow motion.