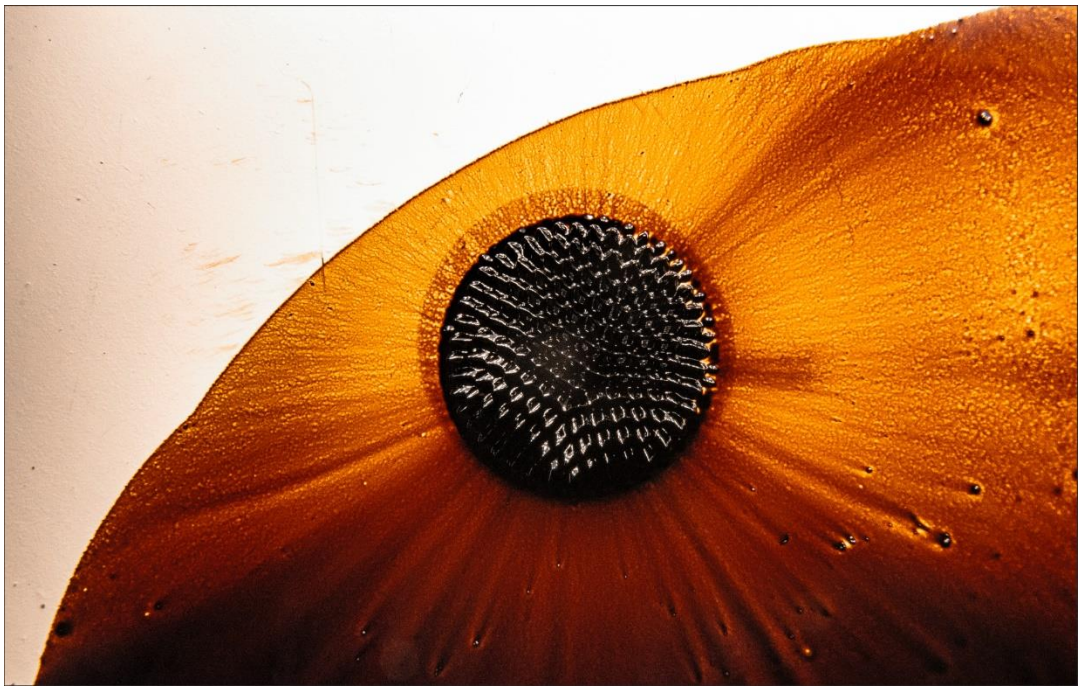
Ferro-Fluid Eclipse



Team Second Report

MCEN 5151

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Introduction:

My team second photo, seen above, involved the manipulation of a ferrofluid using a stud finder magnet. In this experimental setup I wanted to view the magnet's effect on the fluids color, shape, and texture by the magnets effect on the fluids density, layering, internal flows, and overall shape. Using a white dry erase board as a clear consistent background and I attempted to observe the unique shapes formed from magnetic field formed by the stud finder magnet and its interaction with the ferrofluid. The image was framed to portray a presence of other worldly phenomena. When looking at the image and moving the magnet under the fluid I felt like the movement occurring before my eyes was not real, unearthly in a way, and I wanted to present that in my image, With the distinct boundary layer at the top edge of the fluid along with the reflective round central shape that seemed to draw more fluid in to itself I felt like this looked a miniature version of a solar eclipse or black hole. Whichever your interpretation or meaning I felt that this image showed the unique properties the ferrofluid and its intriguing changes in form when manipulated by a strong magnetic field.

Sciences Phenomena

The flow phenomenon occurring within the ferrofluid photographed revolves around the complicated interaction of molecular, magnetic, and gravitational forces. When a magnetic device approaches a ferrofluid, a strong magnetic force interacts with the fluid forming a distinct shape with many spikes as seen in the image beloew. These spikes point typically in the direction of the magnetic field emitted by the magnetic object. The magenta fluid phenomena seen in these images is called the Rosenwieg or normal-field instability. (3) The normal- field instability effect occurs when a certain level of "magnetization" has occurred in the ferrofluid leading to rise of the spikes in the fluid. (3). The normal-field instability and the value of magnetization is highly complicated but is essence is affected by gravity, the permeability of the fluid, the difference in densities across the fluid, its surface tension capacity and most importantly the magnetic field. (3) The spikes form by a variation in the strength of the magnetization across the surface of the fluid in which the spikes and their points have a high magnetization value compared o the troughs in between the spikes which have much lower magnetization values. This shape reduces the overall magnetic energy in the fluid making the shape is favorable for the fluid. (3) When the magnetization is strong enough (in this experimental case the magnet is close enough) a balance between the magnetic field, surface tension, and gravity form these spikes within the fluid. (2) Base on the power of the magnetic field and the fluid properties of the fluid the shape and form can vary dramatically.

The variance in ferrofluid color is simply a function of density and fluid thickness on the surface of the whiteboard. The thicker the ferrofluid across the surface the darker the overall fluid. This enables the distinct color pallet from light brown color in areas of low ferrofluid density and thickness all the way to a striking deep black at center of the ferrofluid circle being affected by the magnetic field. Although it may seem that like this interaction is a fully static fluid phenomena in this case there is some fluid motion in image. The linear streaks shooting out from the magnetized circle are small streaks of ferrofluid slowly being drawn towards the central circle. By using pixel size, the known overall size of the image, and two separate taken two second apart the fluids velocity can be calculated as follows:

Width of Image: 0.2032 meters

Pixels in Width of Image: 6000

Length per Pixel: 0.2032 meters/ 6000 pixels = 3.38 E-5 meters/pixel

# of pixels Moved between Two Images = 25 pixels

Velocity of Fluid = Pixels moved * (length/pixel) / (time between images) =

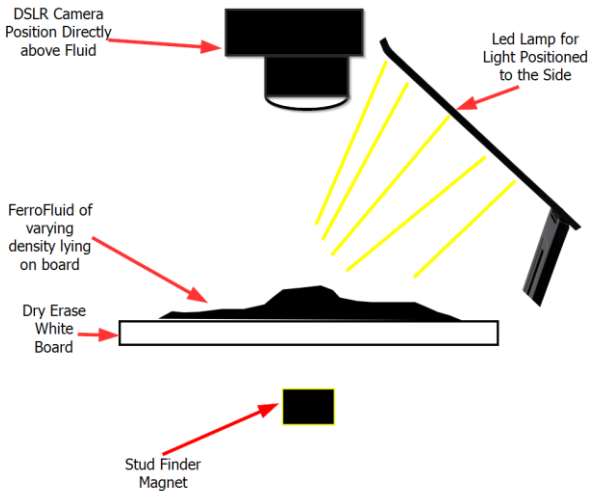
Velocity Fluid = 25 pixels * 3.38 E-5 meters/pixel / 2 seconds = **4.233E -4 m /s**

To determine whether the flow was laminar or turbulent flow within the fluid the Reynolds equation was used as follows: $R_e = \frac{\rho V L}{\mu}$. Where ρ is the density of the fluid, V is the velocity, μ is viscosity of the fluid, and L the length of the fluid in this case the distance flowed. The Reynolds number was calculated as below.

$$R_e = \frac{\rho V L}{\mu} = \frac{1201\,\frac{kg}{m^3} * 4.23\,E(-4)\,\frac{m}{s} * 8.46E(-4)\,m}{6\;\;m\,Pa - s} = 7.16\,E - 5$$

A Reynolds number of 7.16 E-5 meaning the flow is very laminar. Note this is a simplified explanation for the fluid phenomena within this image. More detailed information on the exact formulas for magnetization of the ferrofluid and the propagation of certain shapes based on the value of the magnetic field near a fluid can be found in references 2 and 3 below.

Visual Technique

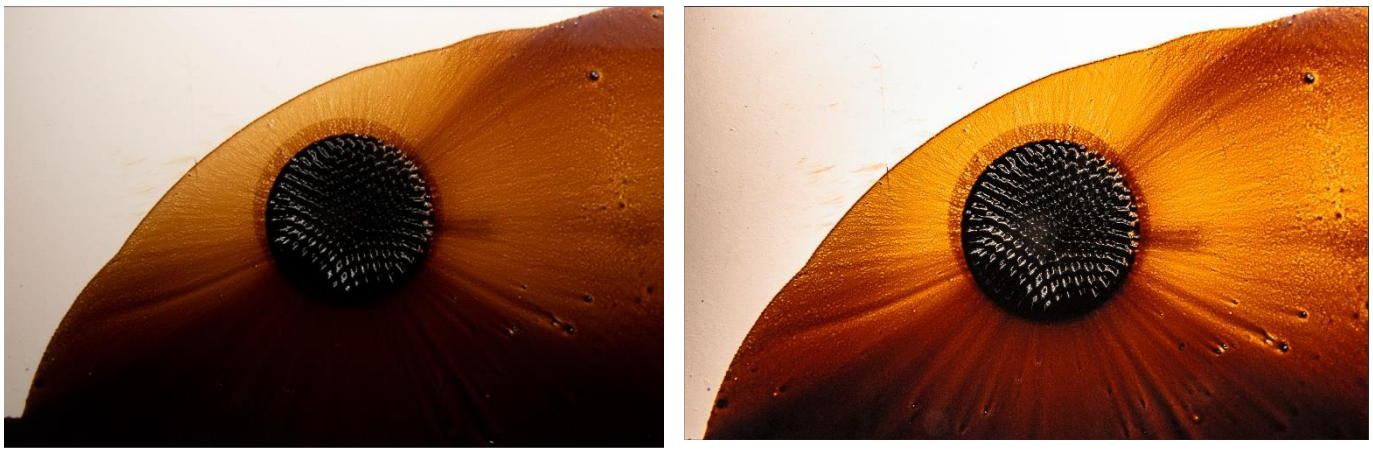


This image taken during the second trial of testing with the ferrofluid which included pouring the ferrofluid obtained from our professor Dr. Hertzberg onto 4X6 dry erase board. As seen in the diagram above a strong magnet found within a stud finder device was used to induce a magnetic field within the ferrofluid. To get the slight differences in density and color in the ferrofluid, the fluid was slowly moved around the board to create a variable thickness of the fluid. This was also enabled by with using the magnet itself to attract and move around the ferrofluid. The image was taken using a Nikon d5500 DSLR camera using a 20mm automatic extender tube at a focal length of 56mm . The extension tube creates more distance between the back of an attached lenses and the cameras sensor. This enables the camera to focus on much smaller and closer objects. This does have drawbacks, First, in using extension tubes, the lense must become incredibly close for the image to become in focus a possible problem when dealing with dirty fluids on a clean lens. Also, the extension tube changes the index of refraction of between the light entering the lens and the sensor within the camera is changing the overall aperture capabilities of the camera as well as reducing the light typically able to be absorbed by the camera with a normal lens setup. With a need for more light to illuminate the subject I used an LED lamp found in team member's Byron Pullastig's lab. The image was shot with a large aperture (f/22) to grasp a wide

range of distances within the image treating the marco object like a landscape shot. To enable a 1/100 shutter speed and small aperture as ISO of 1250 was used for the image enabling the camera to capture enough light despite the drawbacks of the extension tube The full list of camera settings are listed below.

Camera Settings	
Property	Value
Type	Nikon D5500
Shutter Speed	1/ 100 sec
F-Stop	f/22
ISO	1250
Focal Length	60 mm
Image Size	5864 X 3710
Flash Used	No
Cropped?	Yes

As seen in the images below the image was cropped and edited from its orginal RAW format in Adobe Lightroom. To better frame the picture and central subject the image was cropped. To bring out the strong streaks, distinct colors and vibrant shapes with the image I edited the exposure, contrast, clarity, and highlight/shadow levels within the image.



Original (left) and Edited (right) Images

Self Reflection and Future Projects

From both an artistic and scientific perspective, I really enjoyed this project learning about the fluid phenomena of ferrofluids and having the ability to use simple tools to create beautiful natural images. I would like to thank my Team members Robbie Giannela, Max Armstrong, Evan Blake, and especially Byron Pullatasig for their assistance on this project. Byron provided the work

space in his lab for our final imaging of the ferrofluid along with the materials and stud finder magnet. I would like to also thank the Dr. Hertzberg for providing the team with Ferrofluid. I think in the future I would like the experiment more with ferrofluid and use my new knowledge to of the interaction of ferrofluids with magnetic and electromagnetic field to create more distinct and unique art by way of morphing formulaic shapes and forms with this incredible fluid.

References:

1. Odenbach, Stefan, editor. "Ferrofluids." *Lecture Notes in Physics*, FerroFluids: Magnetically Controllable Fluids and Their Application, 2002, doi:10.1007/3-540-45646-5.
2. Knieling, Holger, et al. "Growth of Surface Undulations at the Rosensweig Instability." *Physical Review E*, vol. 76, no. 6, 2007, doi:10.1103/physreve.76.066301.
3. *Polymers, Liquids and Colloids in Electric Fields : Interfacial Instabilites, Orientation and Phase Transitions*, edited by Yoav Tsori, and Ullrich Steiner, World Scientific Publishing Co Pte Ltd, 2009. ProQuest Ebook Central, https://ebookcentral.proquest.com/lib/ucb/detail.action?docID=477092.