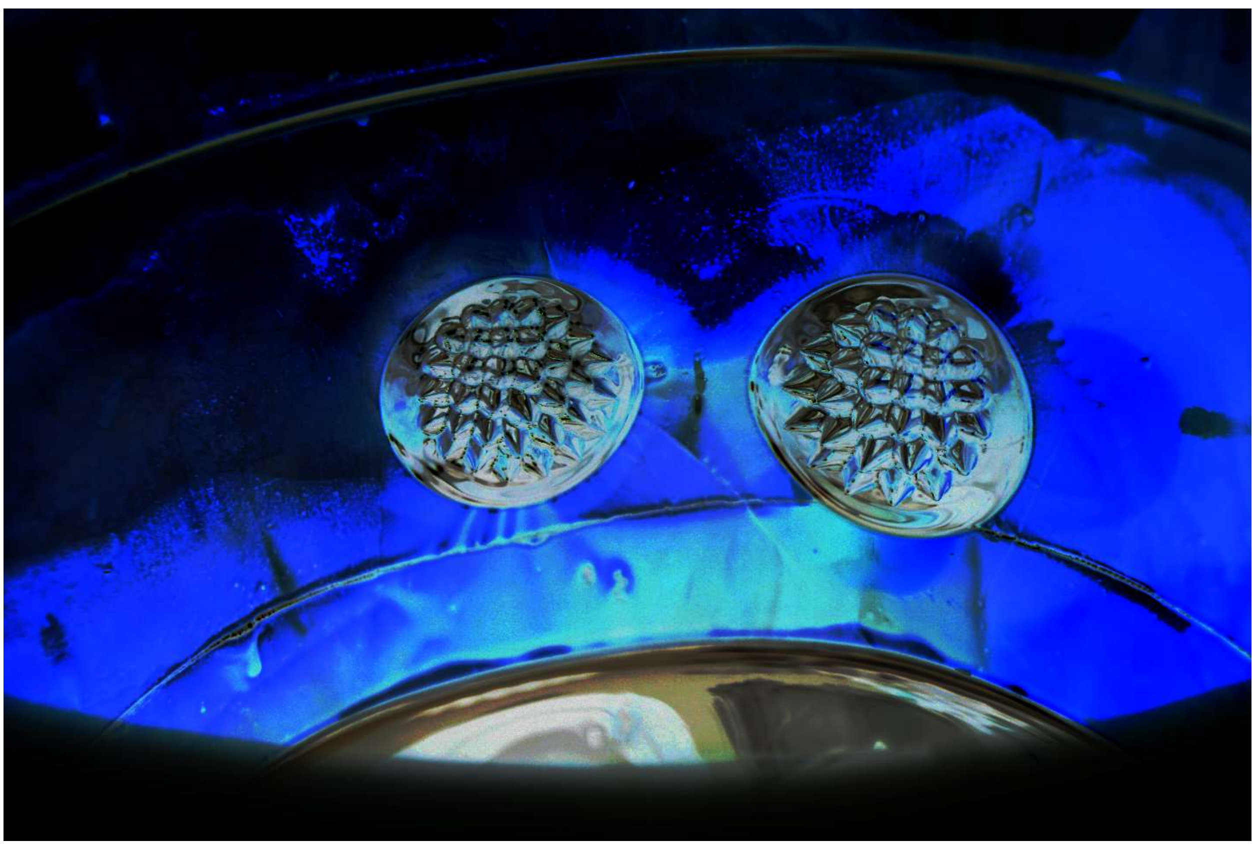
Shalil Jain

Team First

MCEN 5151

10/14/19



For my team first image, I decided to try and create a unique picture using the substance known as ferrofluid. Until this opportunity arose, I had never been able to experiment with ferrofluid, though I had seen this magnetic fluid in action before, whether it be in videos or in the demonstration in the ITLL on the CU Boulder campus. Having witnessed its interesting characteristics, I set out wanting to create something unique as well. Originally, I had the intent to create a video similar to one shown to us in class, where the ferrofluid moved upwards however, after some thought, I decided to pivot from this idea to create a unique picture instead in order to preserve originality. Since ferrofluid is attracted to magnetic forces, I decided to use a pair of "rattlesnake egg" magnets. These magnets are spherical in shape but still have the exact same characteristics and poles like regular bar magnets. Initially, the ferrofluid was placed in a glass plate and the magnets, wrapped in protective saran wrap, were held above the picture by my teammate, Kensue Kiatoukaysy. This did not produce the desired effect I was looking for. So instead, by experimenting with the fluid myself, I began to move the fluid around with the magnet and levitate some of the fluid above the rest of the fluid below it. By using this method, I was able to capture the final image, again, with the help of my teammate.

Ferrofluid is any magnetic material that has been ground into a fine powder with particles no larger than 10 nanometers. These finely ground particles are then suspended in a liquid and the final mixture created from this is what is known as ferrofluid[1]. When ferrofluid is exposed to a magnetic field, it is known to form spikes. These spikes form along the magnetic field lines but only when the magnetic force from these magnets exceeds the molecular forces of the ferrofluid. However, it is the surface tension of the fluid that creates the spike shape[2]. These spikes that form is an example of the Rayleigh-Taylor instability. For a visual representation at the molecular level, see Figure 1 below, which was found from the footnoted resource[3]. The largest of spikes will tend to form where the magnetic field is felt strongest by the fluid. Therefore, the reason the spikes vary in length in the picture I captured is due to the nature of these "rattlesnake egg" magnets. Rattlesnake egg magnets mimic the magnetic field of the Earth or Sun, as they too are simply spherical objects with a dipolar-shaped magnetic field[4]. With this in mind, the spike lengths will be largest in the center of the cluster and slowly grow smaller as they move outward from the center of the cluster (assuming the magnet was perfectly oriented in the picture captured). Since the magnetic force was greater than the gravitational force, the clusters were also able to be suspended above the rest of the ferrofluid pool beneath it.

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[1] "Ferrofluid Fun." PhysicsCentral, https://www.physicscentral.com/explore/action/ferrofluids.cfm
[2] Ibid
[3] "Ferrofluids Spiking." Magnets By HSMAG, 1 Aug. 2016, www.hsmagnets.com/blog/ferrofluids-spiking/.
[4] "Dipolar-Shaped Magnetic Field." Observations of Magnetic Fields - J.P. Vallée, ned.ipac.caltech.edu/level5/March03/Vallee2/Vallee2_2.html.

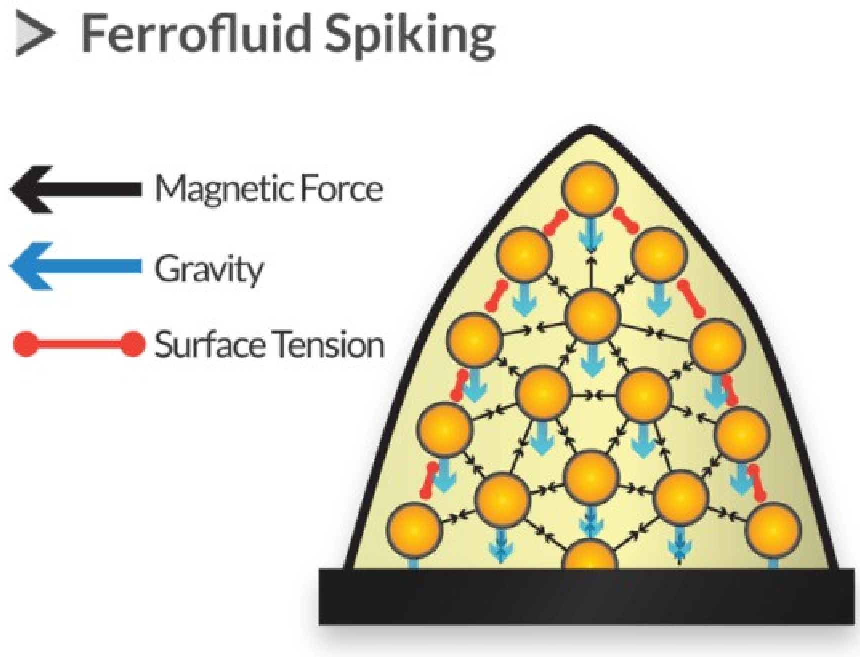

Figure 1: Molecular representation of the physics of ferrofluid

The source of the fluid was given to me by Professor Jean Hertzberg. The picture was taken outside using natural light from the sun, which when hitting earth's surface is approximately equal to 1000 Watts per meter squared[5]. The picture was taken close to midday and therefore, the sun was almost directly above, at a slight southern angle. The setup of the picture was a plastic, clear Tupperware contained the ferrofluid. On the outside of the Tupperware, the magnets were first dragged across the pool of fluid at the bottom of the container and then once the magnetic forces had attracted some fluid, it was then dragged up the side of the container and suspended where it was allowed to settle and become stationary before the picture was taken. The picture was captured at about a 40 degree upward angle relative to the fluid.

[5] "Solar and Sustainable Energy." The Sun's Energy, ag.tennessee.edu/solar/Pages/What%20Is%20Solar%20Energy/Sun's%20Energy.aspx#targetText=At%20the%20upper%20reaches%20of,level%20on%20a%20clear%20day.

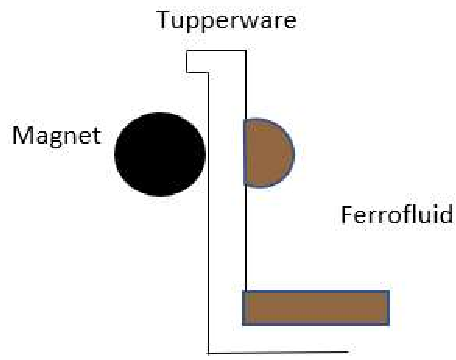

Figure 2: Close up diagram of where the magnet was relative to the fluid

The picture was captured on a Sony A6000, a digital camera. The dimensions of the original and edited picture were 6000 x 4000 pixels. The shutter speed was 1/125 second and the f number was 6.3, with a focal length of 51 millimeters. The ISO setting was 100. The picture was taken approximately 0.3 meters from the fluid. The field of view in this picture is approximately 4 inches by 4 inches. Below is a copy of the original picture and the edited picture. The big difference is of course the color scheme from each version. When I had put this on the Gimp photo editing software, my biggest issue I was having was trying to make the focus on the fluid and not the distracting hand and fingers in the background that were holding the magnets and subsequently the fluid up. I decided to experiment with color inversion and once I did this, I was extremely pleased with the final result. The inversion of color makes the photo and fluid seem otherworldly. Instead of the brown, displeasing natural color of the ferrofluid, the inverted version makes it appear as if the fluid is liquid silver. The inversion of colors also drew more attention to the pool of ferrofluid beneath the suspended clusters, in my opinion. Most importantly, it removes the otherwise distracting fingers in the background. I also decided to not crop out the front lip of the Tupperware as I felt that by leaving this in, it provided a nice frame of focus for the image.

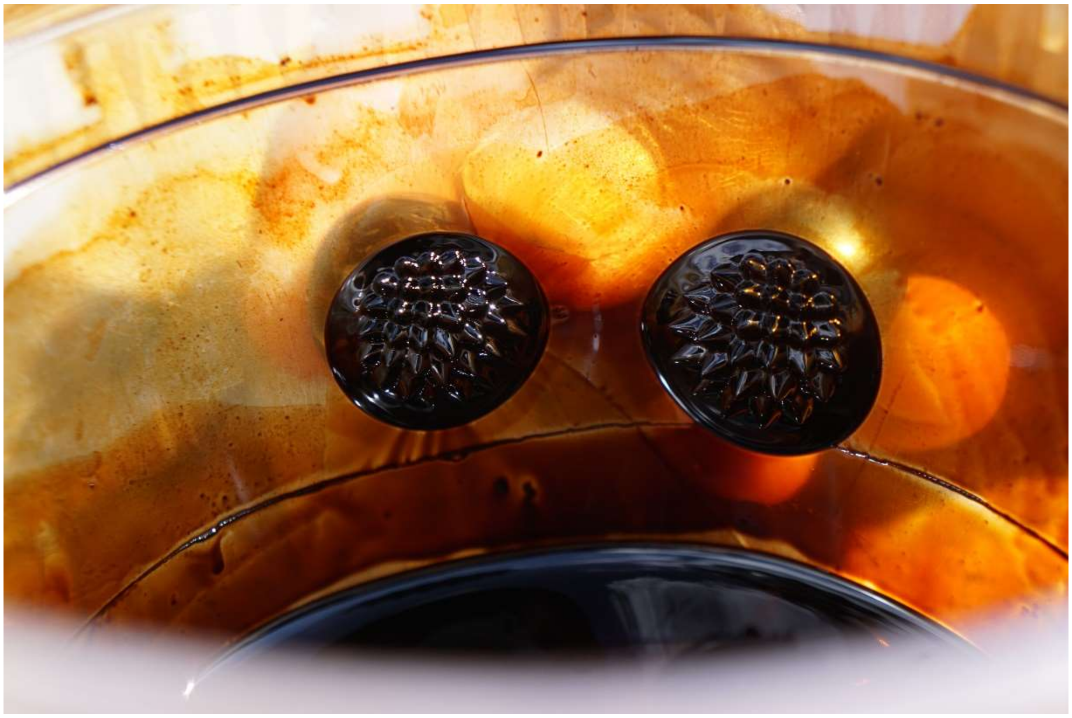

Figure 3: Original Picture

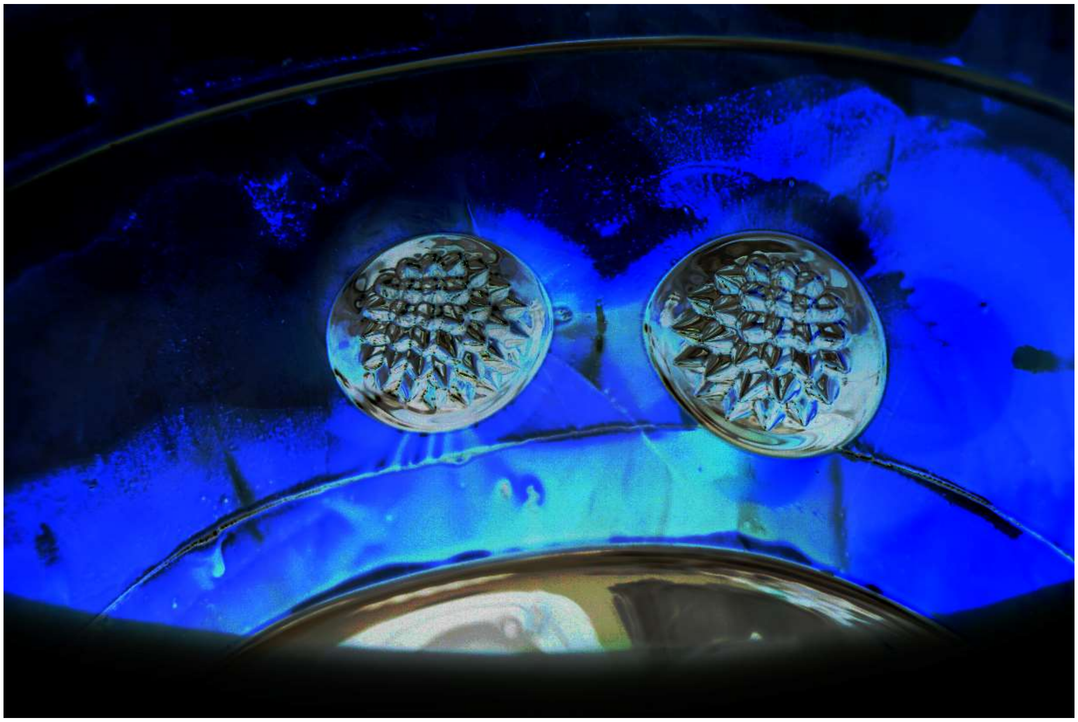

Figure 4: Edited, Final Photo

I am extremely pleased with the final version of the picture. I believe I have truly created not only a great demonstration of the physics of ferrofluid, but a pleasant and otherworldly photograph as well. I really like the color scheme as well as even the splotchy background and reflection in the pool of ferrofluid seen in the final version. There isn't an aspect that I do not like about the final, edited photo. When I had created this image, I had not been entirely sure what the driving force of the spikes in the fluid were however, after doing research for this report, I have answered my own questions about the physics on display. I believe the picture is in focus, which served to be one of the more difficult parts of capturing the image initially as the camera tried to only focus on one cluster most of the time. If I were to continue with this idea, I would perhaps consider creating a video. There was some slight motion created by the magnetic force and this may be interesting to capture on a video device.