SOCIETY OF PHYSICS STUDENTS
An organization of the American Institute of Physics

SPS Chapter Research Award Proposal

Project Proposal Title	Shaping Analysis of Magnetic Ferrofluid
Name of School	William Jewell College
SPS Chapter Number	8235
Total Amount Requested	$510.00

Abstract

The William Jewell College Physics Department would like to examine shaping of ferrofluids in the presence of various magnetic fields and generate computer models of these shapes. Applications for on demand shaping include the disciplines of art, medicine, and engineering.

Proposal Statement

Overview of Proposed Project

Can computer modeling of ferrofluids in the presence of various magnetic fields predict shapes generated by ferrofluids interacting with magnetic fields in a laboratory? This work is relevant in engineering due to the fact that ferrofluids require shaping in order to reduce friction between surfaces. Further, magnetic fluids have been proposed to be used as transportation for drug delivery and for construction of two dimensional designs for prototyping and artistic renderings. The backbone of this research project would be to mathematically model the shape of magnetic fluids under one, two, and multi-pole domains. We plan to begin with an analysis of two magnets interacting with a fluid and progress to multiple electromagnets. We would like for our “field board” to create various shapes on demand and for this, we will need to appropriately configure the wiring and a control system. A prototype of this board has been built and tested. This will develop the methods needed for users to predict and produce two-dimensional shapes. This will provide a stronger base for researches to build to three-dimensional shaping, a much more difficult achievement. This proposed research will introduce a new area of experimental and computational research within our department. This work will complement current fluids work using Schlieren imaging to observe various fluid instabilities. This work will primarily be done with three upper-division students in SPS along with our Society of Physics Students Adviser, Dr. Blane Baker, and an expert in fluid mechanics, Dr. Patrick Bunton. With regards to the Society of Physics Students, the society would be funding a new edge of research along with promoting research in small liberal arts colleges, such as our own.

Background for Proposed Project[3]

Ferrofluids, are systems composed of nanometer-sized magnetic particles suspended within a carrier fluid that allows the fluid to demonstrate magnetic properties when exposed to an external magnetic field. Ferrofluids are considered to be superparamagnetic substances being colloidal suspensions of nanoparticles. These fluids contain a carrier fluid and a surfactant which are typically organic compounds while solid magnetic particles are immersed in the carrier and surfactant mixture. The particles, typically magnetite or another particle with a similar crystalline structure, are magnetic nanoparticles. The surfactant is chemically composed of polar molecules where one end binds to the particle creating a coating around each particle preventing agglomeration and clumping. In ferrofluid, these particles are just large enough to contain a single magnetic domain. When there is no magnetic field present, the particles, as well as their magnetic domains, randomize creating a net magnetic field of approximately zero. When they are exposed to a magnetic field, though, the particles align themselves with the external magnetic field lines. This gives the fluid system a magnetic field itself and depending on the amount of fluid and the intensity of the field, what is known as spiking will occur in areas based from the surface instability. There is also a snaking effect which creates a divot in the fluid surface immediately surrounding the area of instability. One paper has appeared in the literature in the year 2010 describing the shaping of ferrofluids.[2]

Expected Results

We will have a physical model along with working code to predict shaping of these ferrofluids in magnetic fields. These models and computations will be compared to experimental results from our laboratory experiments. We should be able to generate and produce experimental parameters for on demand shaping including electric current required for electromagnets and their arrangement.

Description of Proposed Research - Methods, Design, and Procedures

Background literature research on these fluids has been performed so we will be able to begin conducting experimental measurements once a magnetometer for Arduino is built. Over the course of this semester I have learned and implemented Arduino programs and we will be using that to measure magnetic fields of the electromagnets as well as the region above the fluid with in a field itself because the particles still interact with each other effecting thus magnetic field of the system. This will help us map the fluid shape and how well it conforms to the magnetic field without fluid.

We can then use a petri dish for experiments with multiple magnets. We will be able to get observational data from these, and once we have a consistent grid to map these shapes, we will be able to combine the data to obtain a full picture of the field-fluid shapes. We may need to spend time programming and accessing our programs accuracy.

Once we obtain the appropriate data from these simpler domains, we will be able to begin to build our “field board” creating more elaborate domains allowing us to run more unique tests. When we use the electromagnets, though, their orientation will matter due to the current flow. Alternatively we may arrange two north poles in a row when in fact we would like to arrange a north then a south. This effect was noticed in our previous research.

This project will count towards my research credit in the spring and therefore, I will be giving weekly research talks to our department and update them. This will help keep me on track as well as our department personnel up to date.

Plan for Carrying Out Proposed Project

Dr. Blane Baker has agreed to be the research adviser for the project and Denver Strong would be doing the experiments in consultation with a up to four other students and our fluids expert Dr. Patrick Bunton. All of us are Society of Physics Members.

The extent of our expertise for ferrofluids is limited to our own research carried out this past summer. This includes literature research as well as basic laboratory experiments.

Since our electronics course is not being taught during the semester, we will be using the electronics lab for our experiments along with the general physics lab for some alternative computer programs.

Dr. Blane Baker has agreed to be an adviser for the project and the physics department has donated the space and some of our previously used electromagnets to work on this project. They also purchased our first bottle of EFH-1 ferrofluid from Ferrotec to begin summer research.

Project Timeline

January: build magnetometer circuit
February: write code for measuring the magnetic field
March: obtain experimental data for ferrofluids in the presence of magnetic fields with 2 and 4 poles
April: design and expand our prototype
May: Build and test our new "field board"
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June: compare computer models to experimental data to determine how well predictions relate to experiments

We will also be having weekly presentations within our department from January to May to keep the project on track.

Budget Justification

For this project, we will need Arduino boards and a magnetometer. Our department has the Arduino devices but we do not have the magnetometers. I listed two on the budget just in case something happens, then we will have a back up. Our department also has a set of electromagnets from Arbor Scientific from a project in the spring that our initial prototype is already created from. These will not have to replaced. Although we have a power supply in the department, it is old and unreliable so we would like to replace it to get more consistent data across our trials. We would like to get more and varying kinds of ferrofluid from Ferrotec[1]. We currently have the EFH-1 fluid but we would like to invest in more for a broader range of experimental data. We currently have a few petri dishes in the department courtesy of the chemistry department when were were doing preliminary research but we may need more for the varying fluids and experiments along with disposable pipettes since the fluids stain everything and the measurements are difficult to read after a couple uses. Our department also has the wiring and wood to design and build our field board.

Bibliography

[1] Educational Ferrofluid, https://ferrofluid.ferrotec.com/products/ferrofluid-educational-fluid/efh/EFH1/

[2] Equilibrium shapes of ferrofluid under different forces using continuum shape sensitivity analysis and level set method, Y.S. Kim, I.H. Park, Journal of Applied Physics 9, 107 (2010)

[3] Ferrofluids: Properties and Applications, C. Scherer and A.M.F. Neto, Brazilian Journal of Physics Braz. J. Phys. 35, 718 (2005).