TEACHERS GUIDE

FERROFLUID MAGNETIC DISPLAY

ITEM #3486-00

ENERGY - MAGNETISM

When asked to list off magnetic objects, rarely do we think of liquids, our mind usually goes toward traditional examples: refrigerator doors, nails, screws, and various other objects made of iron and a handful of other metals. The Ferrofluid Magnetic Display provides a delightful surprise to the student exploring magnetism and can inspire new and creative ways of thinking about magnetic fields as well as liquids and solids.

Materials

- Ferrofluid Magnetic Displays
- U-shaped magnet
- Bar-shaped magnet
- Other shapes/strengths of magnets

Goals & Objectives

See page 7 for Next Generation Science Standards (NGSS)

HISTORY

Ferrofluids, or liquids with magnetic nanoparticles in suspension, were first invented by Steve Papell in 1963 for NASA. The original ferrofluid was developed as a liquid rocket fuel that could be drawn toward a fuel pump in the microgravity of space by utilizing a magnetic field. Since then, ferrofluids have been used in electronic devices to form seals, to reduce friction in mechanical engineering, in loud speakers, and in art displays ranging from novelty products to a 2001 art installation by Sachiko Kodama, a renowned Japanese artist.

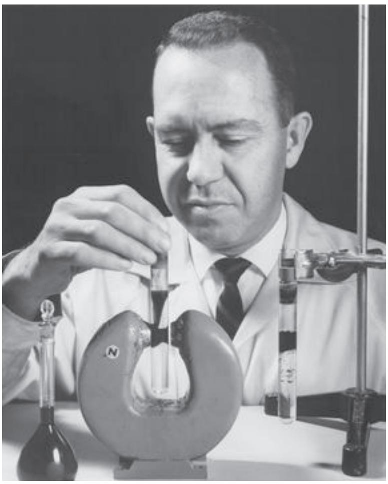


Figure 1:

Steve Papell of NASA and his newly invented ferrofluid.*

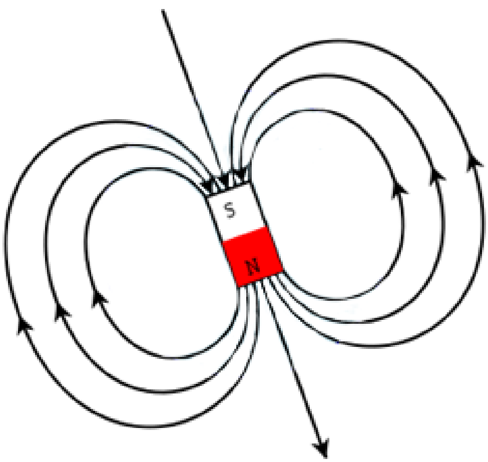
How It Works

The ferroliquid consists of nanoscale iron-containing particles suspended in a liquid. The liquid also contains a surfactant to keep the nanoparticles from clumping together. Given their small size and resistance to clumping, the particles can remain suspended in the liquid and do not sink or precipitate at the bottom thanks to Brownian motion. In other words, the nanoparticles are light enough and small enough that they can be bounced around in all directions due to collisions with the fast-moving molecules of the liquid.

The suspension of solid nanoparticle within a liquid, known as a colloidal suspension, allows the ferroliquid to act both as a liquid and as a solid, depending upon the environmental conditions. In the absence of a magnetic field, the ferroliquid acts as a liquid. In the case of the Ferrofluid Magnetic Display, the dark ferrofluid remains separate from the clear, non-magnetic fluid (mostly water), but still flows and moves like a liquid, taking on the shape of the container. In the presence of a magnetic field, the magnetic nanoparticles line up along the lines of the field, forming spikes or spires that poke into the clear liquid, and behave as a solid. In the absence of gravity or other forces and barriers (such as the walls of the jar), the ferroliquid would form lines completely along the lines of the magnetic field, curving around from one magnetic pole to the other. See Figure 2. However, the force of gravity – and to some extent, the pressure of the clear liquid – prevents continuity along the magnetic field lines and results in peaks and valleys, or spikes.

Figure 2:

The ferrofluid forming lines completely along the lines of the magnetic field.



ACTIVITIES

1 For younger students, focus on science practice skills such as predicting, making observations, and explaining at an age appropriate level. More complex physics concepts can be addressed using the same activities with upper elementary and middle school students. In both cases, the Ferrofluid Magnetic Display lends itself well to active inquiry and student-led investigation.

Engage: The unexpected behavior of ferrofluid makes it a perfect tool to surprise and engage students when used as a demonstration at the beginning of a unit. It could be used to introduce various concepts and phenomena such as states of matter, the effects of objects that are not in contact upon one another, forces, and magnetism.

2 **Explore:** Allow students to explore the effects of the included magnets upon the ferrofluid. You may also want to provide additional magnets such as a U-magnet or bar magnets so that students can explore the effects of polarity and position of the magnets on the fluid.

a. For younger students, the Ferrofluid Magnetic Display can be included in collection of objects that are tested and sorted for magnetic properties. After the objects have been sorted, ask students to consider the characteristics of the objects that react to a magnetic field. Based on their observations of other known materials, can they make any guesses about the contents or “ingredients” of the ferroliquid?

b. Have students pay close attention to cause and effect. As they adjust the distance and positions of the magnets, what are the various results? What are the effects of different strengths of magnets on the liquid?

c. Try lining up 2 or 3 Ferrofluid Magnetic Displays side by side. What do your students notice when they use the magnets to interact with the fluid? Do the ferrofluids in adjacent jars react to one another or tell you more about the magnetic field?

***Note**

It is always wise to DO an experiment ahead of time to be able to best present it to the class.

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ACTIVITIES

Activities continued

3 **Explain:** Have students explain their observations based on what they know about magnetic fields. Encourage the use of models and drawings in addition to words.

Have students use what they already know about magnets and magnetism to make predictions about the contents of the ferroliquid. They should provide evidence and reasoning to support their claims. Challenge them to brainstorm ways of testing their predictions.

4 **Investigate:** Have students generate a number of questions that they have about the ferrofluid. Let them work in groups or as a class to plan and carry out an investigation or experiment to answer one or more of their questions. Potential investigations could test the effects of different kinds of magnets, explore the opposite forces of gravity and a magnet, or even look at the effect of other environmental factors (temperature, movement, etc.) on the behavior of the ferrofluid.

DISCUSSION

Additional Discussion and Real Life Applications

1 Could a material's reaction to a magnetic field be used to describe, classify, or identify the material? How?
How is a ferrofluid like a liquid? How is it like a solid?
Why do the magnetic nanoparticles not stick to each other when the magnets are not present? How do you know they aren't sticking to each other?
Based on your observations, how would you describe the magnetic field around each of the magnets?

Draw a two dimensional diagram or design a three dimensional model to demonstrate the magnetic field and to explain the effect of a magnet on the ferroliquid.
Why does the ferrofluid not continue along the magnetic field lines, forming peaks or spikes, instead?

2 How could the properties of ferroliquids be used to invent or engineer new technologies? Older students can be challenged to design or engineer a new product that uses the unique properties of ferrofluids.

Caution: The Ferrofluid Magnetic Display and included neodymium magnets are not toys. Younger students should be carefully supervised. If swallowed, magnets can cause severe injury or death. Consider substituting larger magnets when working with less mature audiences.

GLOSSARY

Vocabulary:

- Attract
- Brownian motion
- Force
- Gravity
- Liquid
- Magnetic field
- Magnetic force
- Magnetic poles
- Nanoparticle
- Newton's Laws of Motion
- Repel
- Solid

Next Generation Science Standards

Students who demonstrate understanding can:

2-PS1-1. Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

3-PS2-4. Define a simple design problem that can be solved by applying scientific ideas about magnets.

5-PS1-3. Make observations and measurements to identify materials based on their properties.

MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
LS = Life Science
ES = Earth Science

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MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

* [public domain: https://en.wikipedia.org/wiki/Ferrofluid#/media/File:Steve_Papell_NASA_ferrofluid_developer_in_1963.JPG]