Teacher's Preparatory Guide

What does Nanotechnology have to do with Magnetism?- A Ferrofluid Activity

Purpose
Ferrofluid is a unique material that has both magnetic and liquid properties. It is a colloidal solution of nano-sized particle of magnetite suspended in a liquid. This activity will review what students know about magnetism and compares that knowledge to how ferrofluid behaves.
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Time required:
1 hour for teacher prep time
1 -50 minute class period for activity

Level:
Upper middle school to high school

Teacher Background:
General Characteristics of Magnets
1. One end of a magnet is a south seeking end (S) and the other end is a north seeking end (N). Just like with electric charges, "opposites" attract and " likes" repel. So, one magnet's S-pole will be attracted to another magnet's N-pole, and two separate magnet's N-poles (or S-poles) will repel each other.

2. Magnets have invisible "force" fields extending around them just like charges do. We can represent the fields around a magnet with magnetic field lines. The magnetic field has direction, just like the electric field around a charge has direction.

3. Some magnets are permanently magnetic and some magnets are just temporarily magnetic. This is determined by whether the domains are arranged.

4. A domain is just a tiny cluster of atoms within the magnet. Under certain circumstances which cause a material (such as iron) to become magnetic, the domains are all aligned and pointing in the same direction.

5. Permanent magnets are materials that have all their domains permanently aligned. Temporary magnets can temporarily align domains as long as they are in something else's magnetic field.

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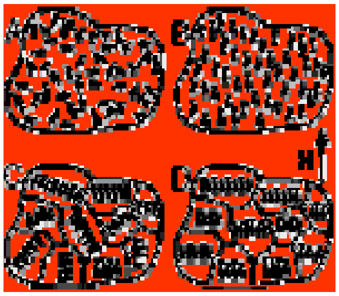

General Characteristics of Ferrofluids

1. Ferrofluids were developed by NASA as a way to control the flow of liquid fuels in space.

2. Ferrofluids are a solution of magnetic particles (on the nanoscale) in a colloidal suspension whose flow can be controlled by magnets or magnetic fields.

3. Ferrofluids are unique in that they have the magnetic properties of a solid but also the fluid properties of a liquid.

4. Commercially available ferrofluids are made of nanosized magnetic solid particles (~ 10nm in diameter) which are suspended in a liquid medium.

4. Today, applications of ferrofluids include low friction seals, computer disk drive seals, loudspeakers, and biomedical applications.

Materials

For each group of students:
Small vial of iron filings
Small vial of iron filings in water
Small vial of ferrofluid
Cow magnet or other strong magnet
For teacher demo
Small petri dish of ferrofluid
Small petri dish of water
Two pennies

Advance Preparation

Teacher will need to order vials, ferrofluid and iron filings and prepare vials. (Information on where the materials that were used in this activity were ordered follow in the resource section.) The amount of material in each vial will depend on the size of the vials. The vials used in this activity used about 5mL of iron filings in each vial containing iron filings, 2 mL of ferrofluid in each vial containing ferrofluid and enough ferrofluid in the petri dish to cover the penny. Enough water was put in the vials containing iron filings and water to fill about ½ of the vial. Once prepared the vials of ferrofluid can be used again. Because the fluid tends to stick to the side of the vial, they will need to be allowed to sit after each use for several hours.

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Safety Information
Be careful when working with ferrofluid since it will cause stains. In addition, it is difficult to remove ferrofluid when it comes in contact with a magnet. For that reason teachers should use gloves, lab aprons, and goggles when preparing vials. Also the vials need to be sealed shut.

Directions for the Activity
1. Using the petri dish of ferrofluid with penny, teacher will show the petri dish and have students observe that the liquid-appearing material covers the penny. Then the teacher will place under the petri dish a strong magnet and again allow students to observe what happens.
(Students will write their observations and what they think is happening which will vary.)
(Placing ferrofluid in a magnetic field causes its density to increase. The penny with rise up over the ferrofluid because its density is now less than the ferrofluid. The teacher should not discuss why this happens until the end of the student activities.)

2. Pass out student worksheet and have students write down what they saw in demo and why they think the penny behaved as it did.
(Students will write their observations and what they think is happening which will vary.)

3. Divide class into groups, and have students complete Activity 1 on Sheet.

4. Discuss answers to questions in Activity 1. (Suggested answers are included on the teacher copy of student activity sheet.) (Also included are some additional questions for discussion.)

5. Teacher will pass out vials containing just iron filings and magnets and groups will complete activity 2.

6. Discuss answers to questions in Activity 2. (Suggested answers are included on the teacher copy of student activity sheet.) (Also included are some additional questions for discussion.)

7. Teacher will pass out vials containing iron filings and water and groups will complete Activity 3.

8. Discuss answers to Activity 3. (Suggested answers are included on the teacher copy of student activity sheet.) (Also included are some additional questions for discussion.)

9. Teacher will discuss what a ferrofluid is. (Use Internet resources to get introductory materials if needed.)

10. Before passing out vials of ferrofluid teacher will caution students that ferrofluid causes stains and is difficult to remove from skin and fabrics. It is virtually impossible to remove ferrofluid after direct with a strong magnet. They are not to attempt to OPEN VIALS. In addition, because ferrofluid sticks to the side of the vials and makes it difficult to see they are not to shake or tilt vial until instructed to do so. Teacher may want to demonstrate how to tilt vial on its side as instructed in Activity 4.

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11. Teacher will pass out vials containing ferrofluid. Students will complete Activity 4.

12. Discuss answers to Activity 4. (Suggested answers are included on the teacher copy of student activity sheet.) (Also included are some additional questions for discussion.)

13. Teacher will again show students the petri dish of ferrofluid and penny and have students go back to their observations at the top of the page and have them make any changes to their rationale to what happened. Ask for students to volunteer to give their observations about what is happening and why.

14. Ask students if there are ways to test their ideas on what is happening. (An extension to this activity would be to allow students to test some of their ideas.)

15. Teacher will discuss that the penny is floating on the ferrofluid because a ferrofluid changes its apparent density in proportion to the strength of the magnetic field that is applied to it. So before the magnet is placed below the petri dish the density of the penny is greater so it sinks to the bottom. When a magnet is near the ferrofluid this increased the density so that it is greater than the density of the penny so that it wants to sink below the penny.

16. Have students answer the conclusion questions. Discuss answers. (Suggested answers are included on the teacher copy of student activity sheet.)

Student Activity Sheet - Worksheet with answers

What does Nanotechnology have to do with Magnetism?- A Ferrofluid Activity

Essential Questions:
1. What does magnetism have to do with nanotechnology?
2. Can liquids be magnetic? Have you ever seen a liquid that is magnetic?
3. How could you keep a liquid in place in outer space where there is no gravity?

Objectives: By the end of this activity you should be able to:
1. Review magnetic characteristics.
2. Discuss the difference in the behavior of liquids that have different size magnetic particles.
3. Discuss what ferrofluid is and some of its uses.

Procedure:
Teacher Demo: Write in the space below what you observed and what you think is happening.
(Students will write their observations and what they think is happening which will vary.)
(Placing ferrofluid in a magnetic field causes its density to increase. The penny with rise up over the ferrofluid because its density is now less than the ferrofluid. The teacher should not discuss why this happens until the end of the student activities.)

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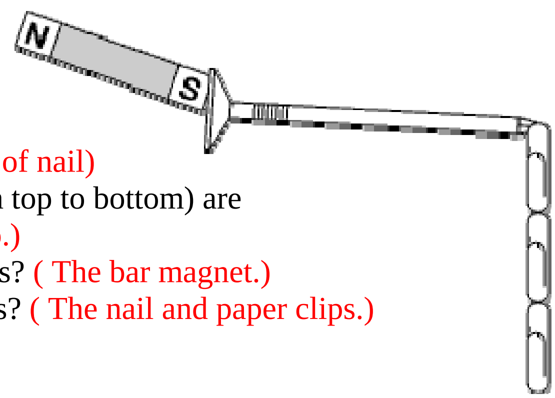
Activity 1: Take a few minuets to discuss with your group the answers to the following questions.

1. A student holds a bar magnet in each hand. If both hands are brought close together, will the force be attractive or repulsive if the magnets are held so that (a) the two N-poles are brought close together and (b) an N-pole and an S-pole are brought together?
   (A) repulsive B) Attractive)
2. The figure to the right shows five disk magnets floating above each other. The N-pole of the top most disk faces up. Which poles are on the top-side of the other magnets? (2nd is S, 3rd is N, 4th is S, and 5th is N)

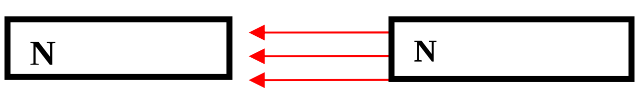
3. The figure to the right shows a magnet attracting a nail to it which, in turn, has attracted many paper clips that are attached to the nail.
   a. Which end of the nail is the N-pole? (top of nail)
   b. Which ends of the three paper clips (from top to bottom) are the N-poles? (The top of each paper clip.)
   c. Which of the items are permanent magnets? (The bar magnet.)
   d. Which of the items are temporary magnets? (The nail and paper clips.)



Activity 2:

1. Along with your group, write down two observations about the vial of iron filings that you have been given.
(Examples of observations are color of iron filings, size of iron filings, that iron is a solid, that iron filings are shiny)

2. On the diagram of the magnets below draw lines that would represent the attractive or repulsive force between the two magnets



3. Do the force lines have a specific direction?
(Yes, from N into S)
4. Take the magnet you have been given and move it around the vial of iron filings, Write one observation about what is happening. (Examples of observations may include iron filings move, forms spikes, follow magnet, are attracted to magnet.)

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5. Would iron filings be classified as a paramagnetic solid (temporary magnet) or a ferromagnetic solid (permanent magnet)?
(Because they are not attracted to other metals, they are only magnetic when in the presence of a magnet, so they are paramagnetic or a temporary magnet.)

Activity 3:
1. Along with your group make two observations about the vial of iron filings and water that has been given to you.
(Examples of observations may include iron filings are at bottom of vial with water above.)
2, Take the magnet and move it around the vial. Write your observations.
(Examples of observations may include iron filings are attracted to magnet and water is not.)
3. Would you say the iron filings are magnetic? Would you say that the water is magnetic?
(Iron filings are magnetic in the presence of a magnet, and water is not magnetic.)
4. When the magnet is removed from around the vial, what happens to the iron filings? Why?
(The iron filings fall to the bottom of the vial because of gravity. And because they are more dense than water they are on the bottom.)
5. What are the similarities and differences between the vial with just iron filings and the vial with the iron filings and water?
(Examples would include that iron filings act the same in both vials. A difference is that one vial contains just a solid the other contains a solid and a liquid.)

Activity 4:
Caution: The ferrofluid causes stains and is difficult to remove from skin and fabrics. It is virtually impossible to remove ferrofluid after direct with a strong magnet. DO NOT OPEN VIAL.

1. Carefully pick up the vial of ferrofluid. Be careful to not shake or tilt vial since ferrifluid tends to stick to the sides of the vial. Along with your group write two observations about this vial.
(Examples may include that the liquid is black, sticks to the side of the vial)
2. Carefully lay the vial over on its side above the table top. Place the magnet you have been given under the vial. Describe below what happens.
(The ferrofluid should form spikes.)
3. Move the magnet around the vial. Describe what happens.
(The liquid should move around the vial with the magnet.)
4. What are the similarities and differences between the vial of iron filings and water and the vial with the ferrofluid?
(In both something in the vial was attracted to the magnet, but in the vial with iron filings and water the liquid did not move with the magnet, in the ferrofluid it did.)
5. What are the similarities and differences between a solution and a mixture?
(Mixtures are the blending of two or more substances together without chemically changing the individual substances in the mixture. Mixtures can then be broken into homogeneous and heterogeneous. A homogeneous mixture is called a solution because is has a constant composition throughout such as air which is a solution of gases and does not scatter light. A solution that has constant composition but does scatter light is called a colloid such as fog. A heterogeneous mixture has differing compositions such as a tossed salad.)

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Activity 5:

Caution: Be careful not to shake the vial around.

1. Inside the container is ferrofluid and a penny. Which do you think is more dense? Why?
(The penny should be on the bottom indicating that it is more dense than the ferrofluid.)
2. Put the magnet under the vial and observe what is happening with the penny.
(You should observe that the penny is trying to get on top of the ferrofluid, which indicates that it is now less dense than the ferrofluid.)
3. Is there a difference in the behavior of the ferrofluid when the magnet is present?
(When ferrofluid is in a magnetic field its density changes and becomes more dense.)

Conclusion:

Answer the following questions.

1. Is a ferrofluid a solid or a liquid?
(It is a collodial solution of a solid and a liquid)
2. Does the solid in the ferrofluid behave the same as the iron filings in the vial of water?
(No, because of the size of the particles the van der Waal forces are greater than the force of gravity so the particles in the ferrofluid are not pulled to the bottom of the vial. Also the magnetite particles in the ferrofluid do not clump together because of the thermal motion of the particles but a surfactant is usually added that applies an electrostatic repulsion between the magnetic particles to help keep them separated.)
3. How was the penny able to float?
(A ferrofluids density is determined by the strength of the magnetic field. In the presence of a magnet the ferrofluid becomes more dense. Before the magnet was placed below the petri dish the penny was more dense than the ferrofluid so it was at the bottom. When the magnet was added the ferrofluid became more dense and it moved to the bottom of the petri dish.)
4. What is considered to be "nano" about ferrofluid?
(Because of the size of the magnetic particles (which are around 10 nanometers) these particles are not affected by gravity which means they will not settle out and they also become more dense in the presence of a magnetic field. Nano-sized magnetic particles behave differently than bulk magnetic materials. This is a demonstration of unique properties at the nanoscale.)

Assessment

Conclusion questions will be used as an assessment tool by teacher. In addition the teacher may want to have the students answer the essential questions on the student worksheet to turn in as an assessment tool.

Resources:

To learn more about nanotechnology, here are some web sites with educational resources:

Ferrofluid, vials, and magnets may be purchased at the following sites:

htttp://www.flinnsci.com (example of prices non-rusting iron filings 500 g @ $9.65, Cow magnets 1@ $11.75

http://www.teachersource.com (example of prices 100 mL of ferrofluid $34.00)

http://www.school.tech.com/magnets3.html

http://mrsec.wisc.edu.edtec/background/ferrofluid/

http://mrsec.wisc.edu/edu/edetc/ferrofluid/index.html

http://chemistry.about.com/od/demonstrationsexperiements/ss/liquidmagnet_5.htm

http://ferrofluidics.com/usa/index.html

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http://www.mrsec.wisc.edu/Edetc/IPSE/educators/ferrofluid.html
http://education.nnin.org

National Science Education Standards

High School Content Standards

- Standard A
  - Identify questions and concepts that guide scientific investigations
  - Understanding about scientific inquiry
- Standard B
  - Structure of atoms
  - Structure and properties of matter
  - Interactions of energy and matter
- Standard E
  - Abilities about technological design
  - Understanding about science and technology
- Standard G
  - Nature of scientific knowledge

Georgia Performance Standards

S3P2 Students will investigate magnets and how they affect other magnets and common objects.
S8P5 Students will recognize characteristics of gravity, electricity, and magnetism as major kinds of forces acting in nature.
SPS10 Students will investigate the properties of electricity and magnetism.
SP5 Students will evaluate relationships between electrical and magnetic forces.
SP6 The student will describe the corrections to Newtonian physics give by quantum mechanics and relativity when matter is very small, moving fast compared to the speed of light, or very large.

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