VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
http://studentorgs.vanderbilt.edu/vsvs

Nanotechnology and Magnetism

Mini Lesson for Fall 2018

Goal: To introduce students to nanotechnology and new magnetic products.
TN state standards:8.ETS1.1, 8.ETS1.2, 8PS2.1

Complete teacher/school information on first page of manual.

1. Make sure the teacher knows Pat Tellinghuisen's home and office numbers (front of manual).
2. Exchange/agree on lesson dates and lesson order (any changes from the given schedule need to be given to Pat in writing via email).
3. Since this is your first visit to the class, take a few minutes to introduce yourselves. Mention you will be coming three more times to teach them a science lesson.

VSVSer **Lesson Outline:**

________ **I. Introduction**
- A. Reviewing Magnetism
- B. Magnets Have Poles
- C. Magnets can be Permanent or Temporary
- D. Magnets have fields (shown by iron filings).

________ **II. Magnetism and Nanotechnology**

________ **III. Nanoscience**

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM
https://studentorg.vanderbilt.edu/vsvs/lessons/
USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

1. Before the lesson:
In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.
Nanotechnology and Magnetism Lesson Quiz
1. What is a magnetic field?
2. How is ferrofluid a unique material?
3. What is nanoscience?
4. What is the difference between permanent and temporary magnets?

2. During the Lesson:
Here are some Fun Facts for the lesson:
The Earth has a magnetic field because there is iron and nickel in the Earth's core.
Earth's magnetic field switches direction every 450,000 years on average. This means that a compass would someday point towards the South Pole.
The iron in our blood cannot be magnetized because it's attached to a protein in your blood cells.
Jupiter's magnetic field is the largest single structure in our solar system besides the Sun.
Many scientists believe birds use Earth's magnetic field as a kind of GPS when they migrate.

Unpacking the Kit

For Part I. Introduction

B. Magnets have Poles, Activity 1: 16 wand magnets, 16 ring magnets on a pole
C. Magnets can be permanent or temporary, Activity 2
16 wand magnets from above, 16 bags containing 5 large paper clips
16 handouts showing temporary and permanent magnets (in sheet protectors)

D. Magnets have fields (shown by iron filings), Activity 3

16 wand magnets (from above), 16 petri dishes of iron filings, 8 pieces of lodestone
16 vials containing iron oxide powder,
8 plastic 3-dimensional magnetic field generators - **Remove bar magnet from plastic container and place on top of red lid before handing out to students.**

For Part II. Magnetism and Nanotechnology

16 Handouts - "How Big Is Your Hand?" and Nanosized objects on reverse size.
Activity 4: 16 vials of iron oxide powder in liquid, 8 vials of ferrofluid, 16 magnetic wands (from above)

I. Introduction

Learning Goals: Students can identify the main magnetic properties and know what permanent, temporary, and induced magnets are.

Vocabulary words: magnetism, lodestone, ferromagnetic, permanent magnet, temporary magnet, magnetic induction, magnetic field, ferrofluid, macroscale, nanoscale, nanotechnology
These words are on the handout, and can be referred to during the lesson.

Why is the science in this lesson important?

Nanotech and Magnetism: Ferrofluids can are currently being research for utilization in precise satellite movements in space. The fluid is being shot through needles for extremely specific control. This research is currently in computer simulation stages.
In ophthalmology, ferrofluid is starting to be used in research regarding retinal detachment, the leading cause of blindness. Because of ferrofluids nanoproperites, the fluid has the potential to seal tiny retinal holes that otherwise cause surgeries to be extremely meticulous and delicate.
To address the BP oil spill of 2010, oil companies have begun to develop new methods for cleaning up offshore oil spills. When oil mixes with water-repellent nanoparticles containing iron, it can be separated from water. The magnetic fluids attach to the oil particles, and the mixture of oil and water can then be filtered with magnets. This way, the water can be returned to the ocean and the oil can be returned to an oil refinery and reused.

Man has been fascinated by magnetic properties since 600 B.C. (One story tells of a Greek shepherd boy called Magnes who discovered that the iron tip on his staff was mysteriously attracted to a rock.) **This rock was a naturally occurring magnetic rock called lodestone.** Lodestone is also called magnetite and is a mineral containing the compound iron oxide, chemical formula Fe_3O_4. NOTE: Fe_3O_4 is not the same as red "rust," which is Fe_2O_3.
Up until about 30 years ago, magnetic materials were known only in the solid form. Tell students that they are going to investigate a new magnetic liquid called ferrofluid and compare its properties with regular magnets.

Your Notes:

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A. Reviewing Magnetism

Ask students to tell you what they know about magnets. Students should know:

- Magnets have north and south poles.
- The south poles on 2 magnets will repel each other. The north poles on 2 magnets will repel each other.
- The north and south pole on 2 magnets will attract each other.
- Magnets have invisible "force" fields extending around them. These "force" fields allow attractions and repulsions to occur without the magnets actually touching.
- This attraction and repulsion is called **magnetism**.
- Some magnets are permanently magnetic, and some magnets are just temporarily magnetic.

B. Magnets have Poles

Materials for each group of 4:

2 wand magnets
1 floating ring magnets set

Activity 1

Divide the class into groups of 4 – each pair in the group will do the 2 activities.

a) Tell 2 members of the group to look at the **wand magnets** and find the labeled north (N) and south (S) poles. Each student will take turns holding the two magnets, one in each hand. Tell students to observe what happens when the two N-poles are brought together (they will repel each other) and when an N-pole and an S-pole are brought together (they will attract each other).
b) Tell the other 2 members of the group to use the disc magnets on a pole and arrange them so that they all float (repel each other). They will start with the magnet in the base having its N pole facing up.
c) Pairs then exchange tasks.
d) Write the observations on the board.

Collect floating ring magnets but leave the wand magnets with the group.

C. Magnets can be permanent or temporary.

Materials per group of 4: 2 wand magnets, 2 bags containing 5 large paper clips,
16 handouts showing temporary and permanent magnets

Activity 2

1. Ask students if they think that the paper clips are attracted to each other, like the 2 magnetic wands. Tell students to test their hypothesis (they should not be).
2. Tell students to use the magnet to pick up a paper clip.
Ask the students if they know why the paper clip is attracted to the magnet.
*Only materials containing metals iron, cobalt or nickel are attracted to magnets. These 3 elements are called **ferromagnetic** (which means they are attracted to a magnet). Most metals (aluminum, copper, lead, silver, gold, etc.) are NOT attracted to a magnet. The prefix <u>ferro</u> comes from the Latin word for iron.*
3. Adjust the first paper clip so that it hangs down from the end of the wand. Tell students to keep the paper clip attracted to the magnet and to pick up another paper clip so that it hangs from the first. Tell students that the first paper clip is now magnetic <u>**by induction**</u>.
4. Try adding a 3rd and 4th paper clip, one at a time, to the bottom clip.

Your Notes:

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5. Remove the paper clips from the magnet and place on the desk top.
6. Ask students if the paper clips are still magnetic. Tell students to use one of the paper clips and try to pick up other paper clips (without using the magnet).
7. Tell students that some magnets are permanently magnetic and some magnets are just temporarily magnetic.

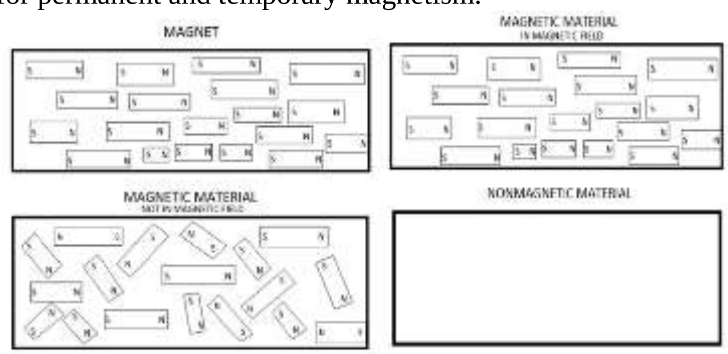
The wand magnet is a permanent magnet. The paper clips are temporary magnets.

Temporary magnets become magnetized in a strong magnetic field but quickly lose their magnetism when the field is removed.

Activity 2b

Use several paperclips to make a chain and hang it from the wand magnet.
Ask students what they think will happen when you remove the wand magnet.
Holding onto the first paperclip, slowly remove the wand magnet. Some paperclips may remain attracted to each other. Eventually they will fall.
The wand magnet (permanent magnet) is strong enough to magnetize the paperclips by aligning the dipoles, or tiny magnets within the paperclip, as shown below. They will remain aligned for a short period until jolted.

Tell students to look at the diagrams on their handout and give a grade-appropriate explanation for permanent and temporary magnetism.



VSVS Background information: Permanent or temporary magnetism is determined by whether the **domains** are arranged. 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. 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.

D. Activity 3: Magnets have fields (shown by iron filings).

Materials:

16 wand magnets
16 petri dishes of iron filings
8 pieces of lodestone
16 vials containing iron oxide powder
8 plastic 3-dimensional magnetic field generators

Your Notes:

<u>Remove bar magnet from plastic container and place on top of red lid before handing out to students.</u>

Pass out lodestone, iron oxide powder and petri dishes.

1. Tell students to move the wand magnet around the petri dish of iron filings.

Ask students to describe what is happening.

Answers might include: the wand magnet makes the iron filings follow it, spikes may form, the filings are attracted to the magnet, etc.

Iron filings can be used to study the pattern formed by the lines of force in the magnetic field around a magnet. The iron filings have been magnetized by induction. They organize themselves into little magnets that point north and south.

2. Tell students to shake iron filings gently so that they cover the bottom of the petri dish in a thin layer.

Place the wand magnet underneath the petri dish and observe the pattern formed. Tell students to twist the wand magnet around in a circle and watch how the positions of the iron filings change. Tell students that there is an invisible pattern of force around every magnet. This force is called a **magnetic field**. The patterns that can be seen with the iron filings are called **lines of force**.

3. Tell students to move the lodestone around the petri dish. What happens? Place the lodestone underneath the dish and observe if there are lines of force patterns.

Is lodestone a permanent or temporary magnet? *Permanent.*

4. What happens when the vial containing iron oxide is placed underneath the petri dish?

   Nothing happens – the powder is not a magnet.

   What happens when the wand magnet is placed near the vial of iron oxide?

   The iron oxide moves to align with the magnetic field.

Which items are permanent magnets and which are temporary?

The wand magnet and lodestone are permanent magnets. The iron filings, paper clips and iron oxide powder (in the vial) are temporary magnets.

Tell students that the iron oxide powder has the same formula as the lodestone (Fe_3O_4).

On the **macroscale**, magnetite, in the form of lodestone, is permanently magnetic.

On the **nanoscale**, magnetite powder is *paramagnetic*, meaning that it's magnetic only in the presence of a magnet.

5. Pass out the plastic 3-dimensional magnetic field generators. **Make sure the bar magnets are sitting on top of the plastic container instead of inside it. Students need to keep the inner tube <u>inside</u> the outer casing.**

Tell students that the plastic containers are filled with iron filings, just like the petri dishes.

Tell the students to gently insert the bar magnet into the center of the plastic container, put the lid on and gently rotate the container. What happens?

The iron filings will be attracted to the bar magnet and should form spikes around the ends.

The accumulation of the iron filings follows the magnetic field lines in 3 dimensions.

II. Magnetism and Nanotechnology

Learning Goals: Students understand what ferrofluid is and why it is different from the powdered iron oxide that isn't nano.

Ask students if they have ever seen a **liquid** that is magnetic.

Tell students that magnetizing a fluid is impossible, because the molecules in liquids have a lot of freedom to move around.

Tell students that **nanotechnology** takes advantage of special properties at the nanoscale to create new materials and devices.

Hold a vial of the **ferrofluid** up so that students can see it. Tell them that the black material is called ferrofluid and that ferrofluid is a unique material that **acts like a magnetic solid *and* like a liquid.**

VSVS Background information only: Ferrofluid is made of tiny (about 10 nm), nanometer-sized particles of coated magnetite (iron oxide) **suspended** in liquid. Ferrofluids were developed by NASA as a way to control the flow of liquid fuels in space. (How could you keep a liquid in place in outer space where there is no gravity?)

Important Idea: At the nanoscale, many ordinary materials have different and unusual properties, compared with the same material at the macro level.

III. Nanoscience

Learning Goals: Students understand the difference between the macro, micro, and nanoscale and can classify different objects as belonging to one of the categories.

Ask students if they know what nanoscience is.

Nanoscale science, or **nanoscience**, focuses on things that are measured in nanometers, including atoms and molecules. In the field of nanotechnology, scientists and engineers make new materials and tiny devices.

Hand out the "How Big Is Your Hand?" worksheet and Nanosized objects (1 per pair).
Tell students to:

1. Look at the scale.
2. Place their hand against the ruler and read off how many nanometers your hand measures.

One meter is a billion nanometers. (A meter is a little longer than a yard.)
Or, **a nanometer is a billionth of a meter.** That's really tiny! Nanometers are used to measure things that are too small to see.
So a person who is a little over three feet tall measures one billion nanometers. A person 6 feet tall is nearly 2 billion nanometers.
Tell students to look at the reverse side, showing the sizes of different objects, measured in nanometers. The pictures are designed to show students ways to think about how small a nanometer is.

There are 3 categories:

1. **Macroscale objects – objects we can see with our eyes.**
2. **Microscale objects – we need tools like microscopes**
3. **Nanoscale objects – we cant see them with just our eyes. We need special tools to make images of them.**

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Why is nanoscience important?
Nanoscience has begun changing products that we use in everyday life, like sunscreen, household appliances, tennis balls, paints, video game consoles, and bandages.
Background Information on Ferrofluids:

Lodestone, the black iron oxide powder and ferrofluid are all made from magnetite (Fe_3O_4).
But the lodestone and the powder do not have ferrofluid's unusual properties.

Ferrofluids are unique in that they have the magnetic properties of a solid but also the fluid properties of a liquid. The nanoparticles are not affected by gravity, which means they will not settle out. They also become denser in the presence of a magnetic field.
When there is no magnet around, ferrofluid acts like a liquid. The magnetite particles move freely in the fluid. When there's a magnet nearby, the particles are temporarily magnetized. They form structures within the fluid, causing the ferrofluid to act more like a solid.
When the magnet is removed, the particles are demagnetized and ferrofluid acts like a liquid again.
Activity 4:
CAUTION: DO NOT OPEN VIAL. DO NOT SHAKE THE VIAL.
Pass out the vials of ferrofluid and iron oxide in liquid. The wand magnets will be used again. Tell them to investigate the magnetic properties of the iron oxide in the liquid (lodestone powder in liquid). Hold the vial horizontally and place the wand magnet above the vial. Describe what happens. *Some of the black liquid moves. The powder clumps.*

Tell students to pick up the vial of ferrofluid.
1. Ask students if the black material is like a solid or liquid.
2. Hold the vial horizontally and place the wand magnet above the vial. Describe what happens. *The ferrofluid should form spikes.*
3. Move the magnet around the vial, including on top of it. Describe what happens. *The liquid should move around the vial with the magnet.*
4. Put the flat side of the magnet on top of the vial so that spikes appear. Gradually move the magnet up and away from the vial. What happens? *Gravity finally takes over*.
5. Ask students what the spikes are showing. *The spikes are a result of the ferrofluid trying to follow the magnetic lines of force.* Tell students to turn the magnet onto its side – what happens to the spikes?

Ask students:
1. Does the ferrofluid behave in the same way as the iron oxide powder in the liquid?
   In both, something in the vial was attracted to the magnet, but in the vial with iron oxide and liquid, some of the solid did not move. The iron oxide clumps more than the ferrofluid.
   The magnetite particles in the ferrofluid do not clump together because of the smaller size of the particles and because a surfactant has been added.
2. What is considered to be "nano" about ferrofluid? *The size of the magnetic particles is on the nanoscale (10nm), which allows ferrofluid to have its unique properties.*

Uses for Ferrofluids
Ferrofluid is used in seals in computer hard drives and other rotating shaft motors and in loudspeakers to dampen vibrations. Ferrofluids are also used in developing MRI images and in

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experimental cancer treatments. In the future, ferrofluids may be used to carry medications to specific locations in the body**.**

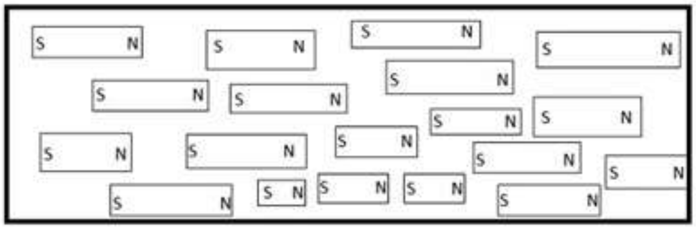
Lesson written by Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Jen Ruddock, VSVS Lab Worker, Vanderbilt University

Your Notes:

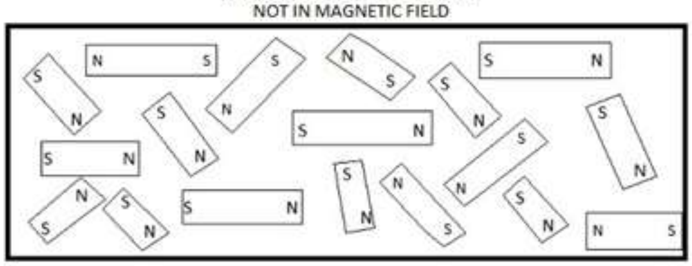
Handout

Vocabulary words: **magnetism, lodestone, ferromagnetic, permanent magnet, temporary magnet, magnetic induction, magnetic field, ferrofluid, macroscale, nanoscale, nanotechnology**

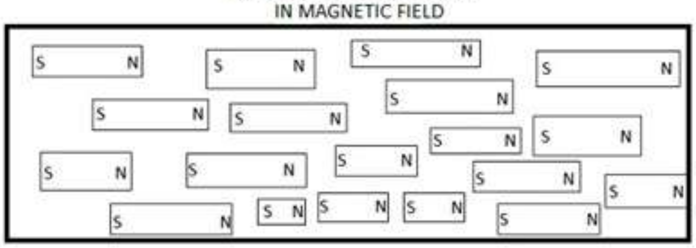
MAGNET



MAGNETIC MATERIAL
NOT IN MAGNETIC FIELD



MAGNETIC MATERIAL
IN MAGNETIC FIELD



NONMAGNETIC MATERIAL

Nanosized Objects

Adapted from Exploring Size – Memory Game from the NISE Network

1. Macroscale objects – objects we can see with our eyes.

A large oak tree is about 20 meters tall

At age 6 or 7, children are around 1 meter tall. One meter is one billion nanometers.

Blue Morpho butterflies have a wingspan of about 15 centimeters (150000000nm)

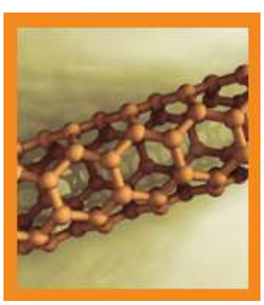
2. Microscale objects – we need tools like microscopes to see them

The diameter of a human hair is around 75,000 nm wide

Pollen, which fertilizes seed plants, can be about 50 micrometers in diameter (50000 nm).

Red blood cells which carry oxygen from our lungs to our bodies, are about 7,000 nm across.

3. Nanoscale objects – we cannot see them with just our eyes. We need special tools to make images of them.



Carbon nanotubes are tiny structures made of carbon, several nanometers in diameter
DNA molecules, which carry genetic code, are around 2.5 nanometers across.
Buckyballs, molecules are made of 60 carbon atoms, are 1 nanometer in diameter