

Magic Sand



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General Description

Cart demo

“Magic Sand” is a cart demo that demonstrates how changing nanoscale changes in a material can affect how that material behaves at the macroscale. Visitors learn that hydrophobic surfaces repel water and that “magic” sand repels water because of a nanoscale hydrophobic coating on the grains of sand. During the program, compare how magic sand and regular sand interact with water.

Program Objectives

Big idea: Nanoscale changes to the surface of sand make it repel water.

Learning objectives:

As a result of participating in this program, visitors will:
See how nanotechnology can change everyday materials
Learn that magic sand is “afraid” of water because it is covered with a nanoscale monolayer of oil-like molecules.

NISE Network Main Messages:

- 1. Nanoscale effects occur in many places. Some are natural, everyday occurrences; others are the result of cutting-edge research.
- 2. Many materials exhibit startling properties at the nanoscale.
- 3. Nanotechnology means working at small size scales, manipulating materials to exhibit new properties.
- 4. Nanoscale research is a people story.
- 5. No one knows what nanoscale research may discover, or how it may be applied.
- 6. How will nano affect you?

Magic Sand / Nanosurfaces

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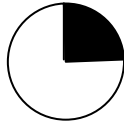
Time Required

Set-up



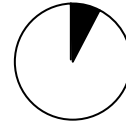
5 minutes

Program



10 minutes

Clean Up



5-10 minutes

Background Information

Definition of terms

Nano is the scientific term meaning one-billionth ($1/1,000,000,000$). It comes from a Greek word meaning “dwarf.”

A *nanometer* is one one-billionth of a meter. One inch equals 25.4 million nanometers. A sheet of paper is about 100,000 nanometers thick. A human hair measures roughly 50,000 to 100,000 nanometers across. Your fingernails grow one nanometer every second.

(Other units can also be divided by one billion. A single blink of an eye is about one-billionth of a year. An eyeblink is to a year what a nanometer is to a yardstick.)

Nanoscale refers to measurements of 1 – 100 nanometers (nm). A virus is about 70 nm long. A cell membrane is about 9 nm thick. Ten hydrogen atoms lined in a row would be about 1 nm long.

At the nanoscale, many common materials exhibit unusual properties, such as remarkably lower resistance to electricity, or faster chemical reactions.

Nanotechnology is the manipulation of material at the nanoscale to take advantage of these properties. This often means working with individual molecules. *Nanoscience*, *nanoengineering* and other such terms refer to those activities applied to the nanoscale. “Nano,” by itself, is often used as shorthand to refer to any or all of these activities.

Program-specific background

Nanotechnology has begun changing products that we use in everyday life, mostly through surface treatments. Visitors may already be aware of stain-resistant Nano-Tex[®] fabric, which exhibits *hydrophobic* (water-repellant or, literally, “water-fearing”) properties. This activity explores magic sand which has similar hydrophobic properties as stain-resistant fabric.

Hydrophobic sand, also known as *Magic Sand*[®], is an example of how nanoscale science can be used to understand drastic changes in a material’s behavior or appearance at the macroscale. Treating the surface of individual grains of the sand makes a new type of sand that behaves very differently from regular beach sand. To understand how hydrophobic sand works, we first must understand some basic principles of water.

Water molecules are highly polar, which means that the molecules have slightly positive and slightly negatively charged ends. Polarity arises when the electrons in the molecule’s bonds are not shared equally between the atoms, creating slightly positive or slightly negative charges on different atoms within the molecule. In water, these charges on the atoms are arranged uniquely, causing the molecule to have a positively charged end and a negatively charged end. The positively charged ends of the one water molecule strongly interact with the negatively charged end of another molecule, much like how the poles of a magnet interact. These interactions are called “hydrogen bonds”, and are directly responsible for some of water’s unique properties (high boiling point, high surface tension, low freezing point, etc). Vinegar (also known as acetic acid) and rubbing alcohol (ethanol) are other polar molecules common in households.

The interactions between the water molecules are so strong that substances made up of non-polar molecules (which cannot form hydrogen bonds) cannot mix with water. Vegetable oil, for example, is made up of non-polar molecules. When the oil comes in contact with water it spreads across the water’s surface, but does not mix with the water. Water either repels or completely envelops non-polar substances so it can continue to bond with itself. *Hydrophobic*, or water hating, molecules are always non-polar, and include greasy substances like oils, fats, or tar.

Natural sand is attracted to water. It is *hydrophilic*, or water loving. At the beach, natural sand surface readily absorbs water when waves crash upon the shore. The atoms on the surface of natural sand particles have positive and negative charges. The charges on the surface of the sand are attracted to the positively and negatively charged ends of the water molecules. Therefore, the water and the sand are attracted to each other.

Using nanotechnology, scientists have created a way change the way sand and water interact. Natural sand grains are coated with a special silicon-based compound. One end of the compound is hydrophilic—therefore it is attracted to

the sand particle. However, the other end of the compound is hydrophobic, so it sticks out away from the grain of sand. This process creates a non-polar (hydrophobic) layer on the surface of the sand grain. The hydrophobic repels water from the surfaces of individual grains of sand.

When magic sand is sprinkled on the surface of water, the water molecules prefer to bond with other water molecules instead of with the magic sand. This prevents the grains of magic sand from breaking through the surface. The magic sand then stays on the water's surface until enough sand accumulates to overcome the surface tension. This same effect keeps magic sand dry. Water molecules will not attach to individual grains of magic sand or flow between them. Other liquids, however, will soak into magic sand. For instance, oil's non-polar nature allows magic sand to be attracted to it and thus allows magic sand to absorb large quantities of oil.

Scientists have found ways to take advantage of the hydrophobic properties of materials such as Magic Sand[®]. Magic Sand[®] was originally developed for use in cleaning up petroleum oil spills. The sand will bond with petroleum oil floating on the surface of water, eventually adding enough weight to make the mixture sink to the bottom. The petroleum oil could then be dredged up from the bottom of the body of water and removed for treatment. Unfortunately, this process requires large amounts of Magic Sand[®], making it too expensive for current use. Nevertheless, if the price of manufacturing Magic Sand[®] decreases, its use for environmental cleanup could become more popular in the future.

Magic Sand[®] has also been used to protect electrical and telephone wires in extremely cold climates. The wires are buried underground for protection from the extreme temperatures. However, when the water in the ground freezes, repairs become difficult and labor-intensive because the layers of dirt covering the wires are very hard. To solve this problem, utility workers first cover the underground electrical junction boxes with a thick layer of Magic Sand[®]. The hole containing the junction box is then capped with a thin layer of normal soil. When water from rain or melted snow seeps into the ground, the layers of Magic Sand[®] repel the water and prevent it from freezing around the junction box. If workers need to perform repairs on the junction box, they only need to remove the thin layer of frozen soil on top of the Magic Sand[®]. The thin layer is easy to break through. Workers can then easily remove the Magic Sand[®] and perform the necessary repairs.

Materials

Activity (for each interaction):

Regular sand (available at most hardware and garden stores)

Hydrophobic Magic Sand[®] (can be purchased through www.stevespanglerscience.com)

2 medium trays to display sand

2 small trays to dump regular and Magic Sand[®] into after straining the water
2 plastic glasses, preferably clear
2 graduated cylinders (25-50 mL)
Two squares of Cheesecloth (large enough to easily cover the mouth of the glasses)
Two rubber bands (optional—to hold cheesecloth in place during straining)
Water (~20-40 mL are needed for each interaction)
Towels (for wiping down cups between demonstrations)
Paper towels and other supplies to clean up sand or water spills
2 tubs or buckets (one to hold wet, used beach sand, one to hold wet Magic Sand[®])

Model:

Magnetic board, available at office supply stores or toy stores (models the surface of regular sand)
Nonmagnetic board (models the non-polar monolayer on Magic Sand[®]. Board can be made from a variety of materials--poster board, plywood, etc--available at local hardware store or lumber yard)
Magnetic “water” molecule models (available at <http://www.3dmoleculardesigns.com/news2.php#water>)
Easel to support magnetic board (and nonmagnetic board)
Poster (provided for download)

Set Up

Time: 5 minutes

Step 1:

Stock supply of regular sand, Magic Sand[®], graduated cylinders and water near plastic glasses.

Prop surface model in stands, with magnetic water pieces and sand “monolayer” nearby.

Pour each type of sand into a separate display tray.

Program Delivery

Time: 10 minutes

Safety:

Very safe. All substances used are non-toxic. Magnetic water molecules are small and may pose a choke hazard for very young visitors.

Procedure and Discussion:

Introduction

Attract visitors to cart, offering them an opportunity to see sand that doesn't get wet. If desired, have some Magic Sand[®] in a cup to entice visitors visually.

Magic Sand Model:

Explain the polarity of water. Ask a volunteer to gently toss water molecule magnets onto the surface of magnetic board, which represents the surface of a grain of regular sand. Explain that the water molecules attach because they are attracted to its surface. Talk about the polarity of the water and the surface of the sand grain as the source of the attraction.

Then, add the "monolayer" to represent Magic Sand[®]. Explain that we are working with a model. The board represents one grain of sand and the sheet represents a monolayer of a silicon-based molecule, 1 nanometer thick. Ask a volunteer to again gently toss the water molecule magnets onto this surface. They will roll off. Explain that they do not stick because the monolayer changes the polarity of the object's surface. The surface of the Magic Sand[®] is non-polar, while the water is polar—therefore they are not attracted to each other. Talk about the interaction of oil and water to reinforce the interaction of polar and non-polar molecules.

Magic Sand Interactive:

Compare magic and regular sand, which is in a tray for easy access by visitors. Allow participants to touch the two types of sand so they can determine that color is the only apparent difference. Measure out equal amounts of each type of sand into two separate glasses (2-3 Tbsp is a sufficient amount). Ask two volunteers to measure and then pour equal amounts of water from a graduated cylinder into the glasses with the sand. The volume of water does not have to be the same each time—but equal volumes have to be used for each glass to allow for easy comparison of the regular sand the Magic Sand[®]. Volunteers should be instructed to remember how much water they used. Have the volunteers gently swish the cups around so the water has an opportunity to mix with the sand. Ask volunteers and other visitors to compare what they see in the two glasses. Cover each of the glasses with cheesecloth and ask volunteers to pour as much of the water back into the graduated cylinder as possible. Compare the amounts of water poured into each glass of sand vs. the amount of water recovered. Explain how regular sand absorbed most of the water while the magic sand repelled it. Finally, pour some of the sand into a tray, and allow visitors to touch so they can see that the regular sand is wet while the magic sand is dry.

Tips and Troubleshooting:

Water and sand can be messy--have cleaning supplies nearby.

The magnetic and non-magnetic board should be the same size.

Painting the non-magnetic board (model of the non-polar surface) that same color as your Magic Sand[®] will reinforce the concept that Magic Sand[®] is non-polar.

Having extra glasses and cheesecloth will help reduce time needed to reset the hands-on demonstration.

To see a video of a UW-Madison MRSEC IPSE intern present this program, go to:

<http://mrsec.wisc.edu/Edetc/EExpo2007/magicsand/index.html> (click on “training video”)

Common Visitor Questions

Why is the Magic Sand pink (or blue, or which ever color you are using)?

Going Further...

Nanotex[®] (stain resistant fabrics)

<http://www.nanotex.com/index.html>

Clean Up

Time: 5-10 minutes

Quick Reset:

1. Wipe up any spilled sand or water from cart surface.
2. Pour waste water from graduated cylinders into jug or bucket.
3. Dump wet, regular sand into large tub.
4. Dump used Magic Sand[®] into large tub.
5. Rinse or wipe out glasses for re-use.
6. Re-set glasses, graduated cylinders and trays for convenient use.

End-of-the-day clean up

1. Wipe up any spilled water or sand.
2. Set aside Magic Sand[®] to dry so it can be reused.
3. Rinse cups for reuse.

4. If regular sand is to be reused, set aside to dry. Sand dries best when spread thinly.

Universal Design

This program has been designed to be inclusive of visitors, including visitors of different ages, backgrounds, and different physical and cognitive abilities.

The following features of the program's design make it accessible:

- [x] 1. Repeat and reinforce main ideas and concepts
 - The overarching main idea is explicitly stated at the beginning of the program, and reinforced by the two activities and subsequent discussion.
 - The Magic Sand Interactive provides verbal, visual, and tactile entry points into the program's main message and learning objectives.
 - The presenter provides a verbal explanation of the differences between regular sand and Magic Sand[®] during facilitated discussion of visitor observations
 - Visitors are invited to feel regular sand and Magic Sand[®] to observe tactile differences.
 - Visitors visually observe the different way that water interacts with sand and Magic Sand[®], both qualitatively (water beads on the top of the Magic Sand[®]) and quantitatively (more water can be recovered from the container of Magic Sand[®] than regular sand).
 - The Magic Sand[®] Model provides verbal and visual entry points into the programs' main message and learning objectives.
 - The presenter provides a verbal explanation of the differences between regular sand and Magic Sand[®] during facilitated discussion of visitor observations.
 - Visitors visually observe differences between water interacting with a "grain of sand" (magnetic board) and a grain of Magic Sand[®] (same magnetic board, covered with a non magnetic surface).
 - The two different hands-on activities give visitors different perspectives of the phenomenon: how does this phenomenon manifest at the macroscale (Interactive) and what is really going on at the nanoscale (Model).

- [x] 2. Provide multiple entry points and multiple ways of engagement

- The program engages visitors in two different hands-on activities and provides a guided discussion that helps them to understand the significance of observations made during the activity.
- Additionally, the program's main messages are reinforced with an accompanying poster that graphically and textually describes the differences between regular sand and Magic Sand[®]

[x] 3. Provide physical and sensory access to all aspects of the program.

- The presenter verbally explains and physically demonstrates tossing the magnetic water molecule models at the model surfaces to appeal to visual and auditory learners.
- The presenter verbally explains and physically demonstrates the measuring and pouring techniques to appeal to visual and auditory learners.
- The presenter can vary the pace of the program to suit the audience, providing extra time for working or additional discussion when necessary.

To give an inclusive presentation of this program:

1. Props used for the Interactive activity (i.e. graduated cylinders, glasses, trays of sand) should be tailored to audience. For example, if fine motor skills are challenging, squirt bottles can be used to measure out the water. Trays of sand should be large enough to see and allow for multiple visitors to touch at the same time.
2. Props used in the Model activity (i.e. magnetic/nonmagnetic boards and molecules) should be made large enough to see by a variety of audiences from a reasonable distance.
3. Accompanying poster should be printed large enough for viewing by a variety of audiences from a reasonable distance.

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