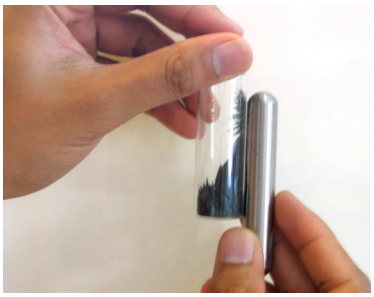
Exploring Materials—Ferrofluid

Try this!

1. Hold a magnet next to the vial of black sand. How does the sand react?
2. Use the magnet to drag the sand up the sides of the vial. What happens when you remove the magnet?
3. Now try the same things with the vial of ferrofluid. Does the ferrofluid act the same way as the sand?



What's going on?

Ferrofluid is a unique material that acts like a magnetic solid *and* like a liquid. In contrast, black sand is a regular magnetic solid. Surprisingly, both ferrofluid and black sand are made of magnetite! The difference in their behavior is due to size.

Ferrofluid is made of tiny, nanometer-sized particles of coated magnetite suspended in liquid. When there's no magnet around, ferrofluid acts like a liquid. The magnetite particles move freely in the fluid. But 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.

Black sand is also made of magnetite, but it doesn't have ferrofluid's unusual properties. That's because the grains of sand are much larger than the magnetite particles in ferrofluid. As a result, they're permanently magnetic and can't be suspended in a liquid.

How is this nano?

A material can act differently when it's nanometer-sized. (A nanometer is a billionth of a meter.) On the nanoscale, magnetite is *paramagnetic*, meaning that it's magnetic only in the presence of a magnet. But on the macroscale, magnetite is permanently magnetic.

Nanotechnology takes advantage of special properties at the nanoscale—such as paramagnetism—to create new materials and devices.

Ferrofluid is used in seals in computer hard disk drives and other rotating shaft motors, and in loudspeakers to dampen vibrations. In the future, ferrofluids may be used to carry medications to specific locations in the body.

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Learning objectives

1. A material can act differently when it's nanometer-sized.
2. The difference in behavior between magnetic black sand and ferrofluid is due to size. On the macroscale magnetite is magnetic, but on the nanoscale it's paramagnetic.

Materials

- Ferrofluid display cell
- Vial of black sand
- Magnets
- Ferrofluid Material Safety Data Sheet (MSDS)

Notes to the presenter

SAFETY: Small fingers can be pinched by magnets! To minimize the pinch hazard, have visitors use caution when holding magnets near magnetic metals.

Before doing this activity, read the information on the ferrofluid display cell provided by the supplier.

Credits and rights

This activity was adapted from the "Quick Reference Activity Guide: Ferrofluids," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Educator Resources, Materials Research Science and Engineering Center on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/ferrofluid.html

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Ferrofluid Background Information

What is ferrofluid?

Ferrofluid is a **colloidal suspension** of small magnetic particles in a fluid. In a suspension, solid particles are dispersed in a fluid. The viscosity of the fluid, the tiny size of the particles, and the particles' constant motion keep the solids from settling out of the fluid. The magnetic particles in ferrofluid are around 10 nanometers in size. (A nanometer is a billionth of a meter.) Particles this size are known as *colloids.*

The magnetic particles in ferrofluids are usually **iron oxide** (magnetite), synthesized in solution and precipitated as nanoparticles:

- Iron salts (iron II chloride and iron III chloride) are mixed in a basic solution. Tiny particles of iron oxide (Fe_3O_4) precipitate from the solution.
- The iron oxide particles are coated with a surfactant to keep them from sticking to each other.
- The particles are dispersed in a water- or oil-based fluid.

Iron oxide is the same compound as **magnetite**, a naturally magnetic mineral found in many igneous and metamorphic rocks. The first ferrofluids, developed by NASA in the 1960s, were ground from natural magnetite.

How can it act like a liquid *and* a solid?

Ferrofluid is **superparamagnetic***,* a property that is found only at the nanoscale. At the macroscale, ferromagnetic materials (like refrigerator magnets) are permanently magnetic. But when ferromagnetic materials are nanometer-sized, they became paramagnetic, which means that they behave like magnets only in the presence of a magnetic field.

When there is no magnet nearby, the magnetite particles in ferrofluid act like normal metal particles in suspension. But in the presence of magnet, the particles are temporarily magnetized. They form structures within the fluid, causing the ferrofluid to act more like a solid. When the magnetic field is removed, the particles are demagnetized and ferrofluid acts like a liquid again.

How is ferrofluid used?

Ferrofluid's properties make it useful for many different applications. Ferrofluid is used in seals in computer hard disk drives and other rotating shaft motors. Ferrofluid is also used in loudspeakers to dampen vibrations. In the future, ferrofluid may be used to deliver medications, using magnetic fields to carry the ferrofluid and medication to a specific location in the body.