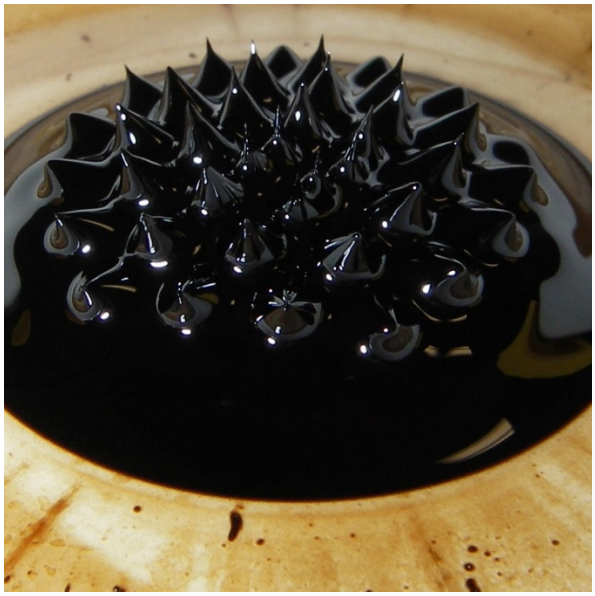
Ferrofluids

Demonstration

This demonstration provides a three-dimensional visualization of magnetic field lines using a ferrofluid.



By Steve Jurvetson (http://www.flickr.com/photos/jurvetson/136481113/) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons

Number of Participants: 2-10

Audience: Elementary (ages 5-10) and up

Duration: 10-20 mins

Difficulty: Level 1

Materials Required:

- Erlenmeyer flask (100 ml)
- Ferrofluid (5 oz.)
- Neodymium magnet
- Bolt or screw

Setup:

Pour 5 oz of the ferrofluid in the Erlenmeyer flask and seal. Be careful with the magnet around electronics and other magnets.

Presenter Brief:

A basic understanding of permanent magnetic materials and magnetic fields is required.

Vocabulary:

- Ferrofluid – A colloidal liquid made of nanoscale ferromagnetic particles suspended in a fluid.
- Colloid – A mixture in which one insoluble substance is suspended throughout another substance.
- Ferromagnetic – Substances like iron, nickel, cobalt, and rare earth metals that are permanent magnets and can be magnetized by an external magnetic field.

Physics & Explanation:

Elementary (ages 5-10):

Ferrofluids are liquids that become magnetic in the presence of a magnetic field. Specifically, ferrofluids are made by suspending nanoscale ferromagnetic (or ferromagnetic) particles in a carrier fluid. An example of a simple ferrofluid is iron oxide (rust) dust put into vegetable oil. When exposed to a magnet, the fluid will act like a magnet and will move around.

> Explain that when you hold a magnet near a refrigerator, you can feel the two attract. The magnetic field is interacting with the metal on the refrigerator.
>
> You can also have two magnets on hand to show that the magnets attract and repel each other. Stress that the magnets push each other without touching.
>
> Carefully move one pole of the magnet to the bottom of the flask until spikes appear in the fluid. Since the liquid has tiny metal pieces inside, it allows us to observe the magnetic field of the magnet.

🔑 Magnets can attract and repel other magnets and metals.

Middle (ages 11-13) and general public:

Ferrofluids are composed of oil, a surfactant (compound that lowers surface tension, such as soap), and magnetite particles. The nanoparticles in ferrofluids can be as small as ~10 nm in size. Using magnetic fields (produced by a magnet) we can visualize these fields in three dimensions using ferrofluids.

> Carefully move one pole of the magnet to the bottom of the flask so that pole is normal to the bottom of the flask. 3D spikes tracing the magnetic field lines should appear in the fluid.

The individual magnetite particles' magnetic fields are weak enough so that the surfactant keeps the particles separate and magnetic clumping does not occur.

> Rotate the magnet so that the field lines are perpendicular to the bottom of the flask. The spikes should disappear. Continue rotating the magnet to show the spikes following the magnetic field lines as depicted in Figure 1.

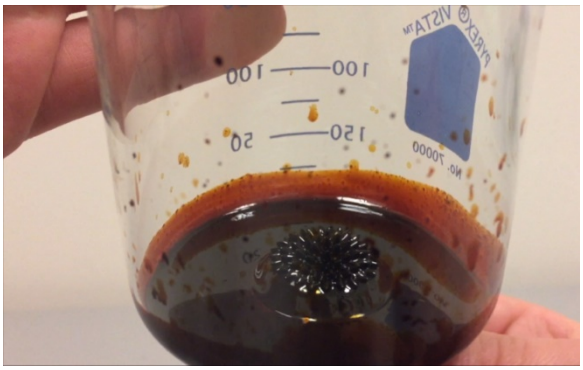


Figure 1

🔑 Magnetic fields are three-dimensional and can be visualized with ferrofluid.

Objects can become magnetized without even touching a magnet.

> Find a bolt or screw that can be placed in a beaker or petri dish and is strongly attracted to a magnet. Place the magnet under the container/beaker/dish and the bolt above the container/beaker/dish so that the magnet is magnetizing the bolt. Very slowly drip the ferrofluid onto the bolt/screw. The ferrofluid will align with the magnetic field lines of the screw/bolt and should form interesting patterns.

🔑 Magnetic fields from three-dimensional objects can be very complex. Materials can be magnetized without touching a magnet. The ferrofluid shows us the induced magnetic field.

Additional Resources:

- Knight, Jones, and Field, College Physics: As Strategic Approach, 3rd Ed. (2014
- 2012 SOCK https://www.spsnational.org/sites/default/files/files/programs/2012/sock/2012-sps-sock-manual-final.pdf