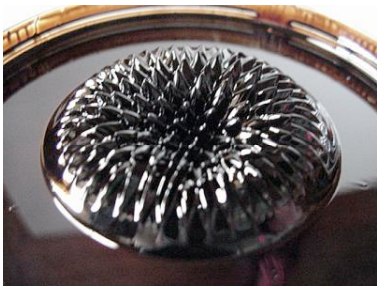
Magnetic Fluid (Ferrofluid)

Introduction



Ferrofluid is a magnetic fluid made out of nanometer sized pieces of iron or various iron oxides, suspended in a liquid. The shapes and flow of ferrofluid are surprising and beautiful, and show how magnetic field lines curve around magnetic objects.

Materials

To make ferrofluid, you need three things:

- some form of tiny (around 100 angstroms) iron particles
- a surfactant (ie., emulsifier, to keep the particles from clumping)
- a carrier fluid (to make it flow)

You can buy your ferrofluid commercially for $30 for 100 ml (or $150 for 1000 ml – pool together and get some!) at http://www.teachersource.com/direct/34960.

You can also make your own with the following methods:

1. Nano-sized iron powder: http://exo.net/~jillj . The water glass is quite viscous and so the peaks formed are not as sharp as with commercial fluid.
2. VCR tapes: Find really cheap VHS tapes and pull out the tape. Stretch the tape to double its length, and rub it against a butter knife.
3. Laser toner: You can get the iron particles from magnetic laser printer toner, but we at the Exploratorium haven't tried this (yet). Not all laser printer toner is magnetic. http://www.hackaday.com/entry/1234000107073725/
4. Burn steel wool to get iron oxide particles
5. Get Magnaflux from a welding shop.

Once you have iron particles, they can be suspended in corn oil, mineral oil, or lightweight motor oil. Some suggest a mixture of isopropanol and water, but anything with water will cause your iron to rust. The less viscous the carrier fluid, the more dramatic the peaks will be. Finding a good surfactant so you have a suspension, rather than iron sitting in the bottom of a bottle of fluid, is the challenge. On the other hand, iron sitting in the bottom of a bottle of fluid is also pretty neat to play with. We don't yet have a good safe surfactant to recommend. Some that are used are oleic acid, citric acid, and tetramethylammonium hydroxide (very toxic!).

Contact me if you are interested in ferrofluids, as I will be continuing to experiment.

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To Do and Notice

Very strong magnets work best to see behavior with the fluids. If you use neodymium magnets, BE CAREFUL. Two neodymiums can snap together, breaking the bones in the fingers or giving nasty blood blisters. Neodymiums will also erase credit cards and computer memory.

You can see neat behavior by any of the following:

1. Pour ferrofluid into a Petri dish, or in a vial or test tube, and put a magnet underneath
2. Put clear mineral oil in a vial or test tube and add a small amount of ferrofluid, and put a magnet next to it.
3. Put nuts and bolts and other steel/iron objects in the ferrofluid and bring a magnet close to it. Make sure there is something between the magnet and the iron object (such as a Petri dish) or else the iron object will jump to the magnet.
4. Attach a string to a stack of magnets, and lower into a test tube. From above, lower the test tube towards ferrofluid in a Petri dish. The ferrofluid will leap from the Petri dish to the bottom of the test tube, defying gravity and delighting the audience. The magnet underneath isn't necessary, but it makes the jump a little more dramatic. You should be able to remove the magnets from the test tube (without the ferrofluid following up the outside of the tube) by pulling them up very swiftly (making the fluid fall back into the petri dish). Alternatively, you can cut a hole in a rubber stopper the size of the test tube, and fit that over the test tube before the demonstration – the rubber stopper will stop the ferrofluid.

Two words of caution: (1) Ferrofliuds stain. (2) Every demo will result in some lost ferrofluid. It's difficult to recapture all of it.

Etc.

It's generally difficult to make a magnetic liquid because once you melt a magnetic material (like iron) it's not magnetic anymore. Past the *Curie point* magnetic materials lose their magnetism – the thermal energy in the metal overwhelms the tendency of the magnetic domains to align with each other. The melting point for iron is 1000˚C, but its Curie point is 800˚C. Ferrofluid was originally developed by NASA because they needed to be able to control liquids in low gravity. Today they're used to damp high-end speakers, as liquid seals in hard drives, and other applications.

Other Resources

Some neat shapes, easy to make: http://www.wondermagnet.com/ferro.html
Beautiful art, harder to make: http://www.kodama.hc.uec.ac.jp/proflo.html and http://www.mi.sanu.ac.yu/vismath/takeno/

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