Ferrofluid

Overview: Today going to learn about liquid magnets, also known as ferrofluids. Ferrofluids are what scientists call "colloidal suspensions," which means that the substance has properties of both solid metal and liquid water (or oil), and it can change phase easily between the two. And make a total mess.

What to Learn: Ferrofluids are what scientists call "colloidal suspensions," which means that the substance has properties of both solid metal and liquid water (or oil), and it can change phase easily between the two. Because ferrofluids can change phases when a magnetic field is applied, you'll find ferrofluids used as seals, lubricants, and for many other engineering-related uses.

Materials:

- Old toner cartridge from a laser printer or copy machine
- Strong magnet (neodymium magnets work best)
- Paper or newspaper
- Baby oil or vegetable oil
- Plastic bag
- Metal bolt with nut and large washer
- Disposable plastic cup with lid
- Popsicle stick
- Medicine dropper
- Gloves and goggles
- Adult help

Lab Time

If you work with toner, you will make an absolute mess. It will get in places you never thought possible, which is why this lab is perfect as a parent-kid activity. Wear old clothes, goggles, gloves, and be prepared to have a lot of fun.

1. Watch the video and see where you need to punch holes (if needed) in your toner.
2. Wearing gloves, remove as much of the powdered ink as you possibly can onto a sheet of paper.
3. Funnel the powder into the cup. You might want to save some for later in case you'd like to experiment with different solvents. You can use baby oil, water, or alcohol to mix the fluid with. The experiment in the video uses oil.
4. Add a little baby oil to the cup and stir with a popsicle stick.
5. Bring a magnet to the outside of the cup and watch the magnetic liquid stick to the side of the cup!
6. Don't get the magnet above the rim of the cup, or the ferrofluid will stick to the magnet and you'll never get it off again.
7. Play with the ferrofluid:
    a. You can thicken it up by adding more powder to the mix. This will form a magnetic putty you can play with as long as you have gloves on your hands. If you leave it on the table close to a magnet, it

will slowly creep toward the magnet. Add a tiny bit more liquid if it doesn't appear to move over the course of 10-20 minutes.

b. Thin it out with more oil to make it more like the commercially available ferrofluid. You'll get more spikes, especially if you let it sit for a couple of hours to completely immerse in the oil.
c. Bring a magnet close but not touching the cup. What happens?
d. Make a larger magnetic surface for the ferrofluid to interact with:
    i. Place 1-2 strong magnets (neodymium work best) under your plastic cup. If it's not stable, add a large washer to the bottom of the magnets to make a stand.
    ii. Thread a nut onto a bolt a few turns (not all the way – leave it near the base) and upright in the cup so that the bolt is standing up on its own. The magnets will keep it stable.
    iii. Using a medicine dropper, slowly drip the ferrofluid onto the top of the bolt. If you pour it too quickly, the fluid will splatter and be very messy to work with. Make sure your ferrofluid is relatively thin for this process. You can use the ferrofluid you created or the stuff from a store.
    iv. Bring a magnet close (not close enough for it to jump onto the bolt, or you'll make a huge mess) and observe what happens. What is the furthest you can move the magnet and still influence the ferrofluid?
    v. What happens if you try a different magnet?

Reading

The ink inside your toner cartridge is powdered ink. Even an empty cartridge will have extra powdered ink inside. The ink has little bits of iron mixed in with the ink. If you extract the ink and mix it with oil, you can make your own ferrofluid.

A ferrofluid becomes strongly magnetized when placed in a magnetic field. This liquid is made up of very tiny (10 nanometers or less) particles coated with anti-clumping surfactants and then mixed with water (or solvents). These particles don't "settle out" but rather remain suspended in the fluid. The particles themselves are made up of magnetite, hematite or iron-type substance.

Ferrofluids don't stay magnetized when you remove the magnetic field, which makes them "super-paramagnets" rather than ferro-magnets. Ferrofluids also lose their magnetic properties at and above their Curie temperature points.

Engineering and scientists use ferrofluids to make a liquid seal in hard drives around the spinning disks to keep out dust and grit (hard drives must be kept exceptionally clean!). They do this by adding a layer of ferrofluid between the rotating shaft and magnets which surround the shaft.

You can also use ferrofluids to reduce friction, the way ice and water are used in ice skating rinks. If you coat a strong magnet with ferrofluid, you can get it to glide across a smooth surface like a hockey puck. NASA uses ferrofluids in the flight instruments for spacecraft, also!

Each particle of ferrofluid is like a each grain or a micro-magnet, which not only interacts with magnetic fields, but also with light.

With loudspeakers, the large magnets that interact with the coil often heat up. If we replace the magnet with ferrofluid (which is a liquid, remember!) it will actively conduct the heat away from the coil and cool it down because cold ferrofluid is more strongly attracted than hot, and thus the cooler fluid flows toward the coil, and the warmer fluid moves away from the coil.

Notes on the Lab: If you prefer, you can purchase a premade ferrofluid kit, but I prefer to show the kids where the fluid itself really comes from so it's not such a mystery after we're done. I usually have commercially available ferrofluid also to play with and compare after we've made our own. Feel free to skip this lab if the materials are out of your budget, or save it as a treat for a special time. You'll get lots of ooh-ahhs if you perform this for an adult.

Exercises

1. Is the ferrofluid a solid or a liquid?
2. Does the strength of a magnet matter?
3. What would happen if the magnet went over the rim of the cup?
4. Does the ferrofluid have a north and south pole?
5. What happens if you bring a compass near the ferrofluid?
6. Name three specific ways ferrofluid makes our lives easier. How might you use a ferrofluid if you were inventing something?

Answers to Exercises: Ferrofluid

1. Is the ferrofluid a solid or a liquid? (Both, depending on the conditions it's placed in.)
2. Does the strength of a magnet matter? (Yes. The stronger the magnet, the more the ferrofluid interacts with the magnet.)
3. What would happen if the magnet went over the rim of the cup? (Don't get the magnet above the rim of the cup, or the ferrofluid will stick to the magnet and you'll never get it off again.)
4. Does the ferrofluid have a north and south pole? (Ferrofluid is made up of very tiny particles mixed with water. These particles don't "settle out" but rather remain suspended in the fluid. Each tiny particle has a north and south pole.)
5. What happens if you bring a compass near the ferrofluid? (Nothing, until you bring a magnet close by. But ferrofluid can conceivably be used as a compass.)