timefornano

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instructions

ferrofluid

Health and safety

Ferrofluid needs to be handled with care and should not be shaken.

The test tubes should not be opened. If the ferrofluid breaks do not throw it in the sink; it must be disposed of as motor oil.

In case of contact with skin, wash with copious amounts of water and soap.

The ferrofluid inside the test tube is flammable

What happens in this experiment?

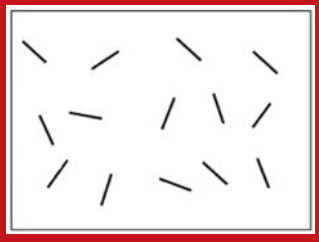
This experiment aims to show how the properties of a solid can change at the nanoscale.

Ferrofluid is a suspension of magnetite nanocrystals which are around 10nm across. The crystals are covered by a membrane of special material, called a surfactant: a material that strongly reduces the attractive forces between nanocrystals. This isolates every single nanocrystal from the attractive forces of nearby nanocrystals and prevents them from clumping together and forming a single solid mass.

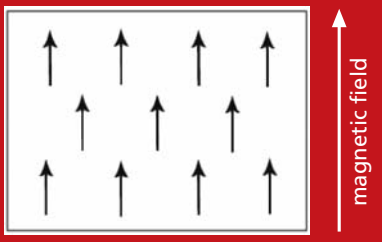
When there is no magnet present, ferrofluid particles move freely in the liquid. In the presence of a magnet, the particles are temporarily magnetised and the ferrofluid acts more like a solid. When the magnet is removed, the particles lose their magnetisation and ferrofluid behaves like a non-magnetic liquid again. This behaviour is called 'superparamagnetism'.

When an external magnetic field is applied, the originally random organisation of the nanoparticles changes and they immediately align to the magnetic field, becoming magnetic themselves. So ferrofluid is a liquid material that has solid properties when submitted to a magnetic field. But: ferrofluid is not a liquid magnet!

This is different from the magnetite sand which is always magnetised.



When all the nanoparticles are randomly organized in the absence of a magnetic field, the ferrofluid is a non-magnetic fluid



When all the nanoparticles are aligned in the magnetic field, the ferrofluid becomes magnetic

Applications

Making a ferrofluid is not quite as simple as mixing tiny particles into a liquid. The particles need to be so tiny that they cannot be made just by crushing or scraping a magnetic material but must be precipitated out of a solution.

Ferrofluids were originally developed in the 1960s at the NASA Research Centre, where scientists were studying different possible ways of managing liquids, especially fuel. In space there is no gravity so liquid materials do not stay in a glass and cannot be poured from one container to another! The scientists were able to make a new kind of liquid that can be driven and controlled through the application of a magnetic field.

Ferrofluid's proprieties make it useful for many different applications. Computer hard disk drives and other rotating shaft motors use ferrofluid in their seals, while loudspeakers use ferrofluid 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. Using electromagnets and sensors, the thickness of ferrofluid can be controlled dynamically; some sports cars use this in their active damping suspension systems.

Some organisms use nanocrystals of magnetite. During migration, trout can orientate themselves using magnetite crystals in special cells in contact with their central nervous system that are used as a compass. The bacterium *Magnetotacticum bavaricum* is able to produce nano crystals of magnetite.

Ideas for conducting the activity or discussion

- You could ask the children what they think ferrofluid is and what is the difference between magnetite sand and ferrofluid.
- You could ask them what applications ferrofluid could have.

Learning objectives or school curriculae

- To introduce magnetism.
- To understand the different behaviours of matter at macroscopic and nanoscopic scales.
- To have an idea of how scientists and engineers are able to manipulate matter at the nanoscale.