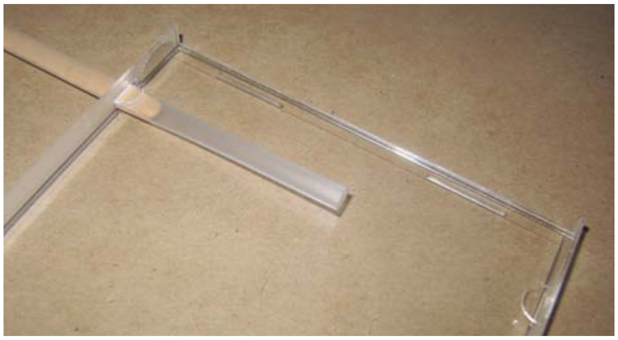
Magnetic Force Microscopy

Investigating tools that scientists use to probe the nanoscale.

Assembly

1. Cut the small straw in half. You now have two small straws.
2. Flatten one end of a small straw and use a pushpin and scissors to make a 3-mm (1/8 in) hole near the end. A 1/8" hole punch works well if you have one. If the hole breaks through either side, just cut off that part of the straw and try again.
3. Place the small straw on top of the wooden stick so the end with the hole hangs off about 2 cm (1 in).
4. Holding the small straw and the wooden stick together, slide both of them into the large straw. The wooden stick should go all the way into the large straw and the end of the small straw with the hole should stick out about 2 cm.
5. Insert the tiny magnet into the hole in the small straw as shown.
6. Insert a toothpick into the end of the small straw on either side of the magnet.
7. Slide the other small straw over the ends of the toothpicks. This assembly of straws, wooden stick, toothpicks and tiny magnet is called the "cantilever".
8. Open the cover of one of the jewel cases (without a media tray).

9. Pinch the end of the large straw (farthest from the tiny magnet) and slide into one of the slots in the jewel case cover as shown.
10. Slide the cantilever through the slot until the large straw goes through the slot on the other side of the jewel case cover (about 1 cm), and close the jewel case.
11. If you need to raise your cantilever, you can place the other jewel case underneath the one with the cantilever.



Try this!

1. Place a sample magnet underneath the tiny magnet in the cantilever. If the tiny magnet sticks to the sample magnet, you will need to raise your cantilever by stacking it on another jewel case.
2. Slowly slide the cantilever so the tiny magnet moves over the sample magnet. Notice how the tip of the cantilever moves up or down as it passes over the sample magnet.
3. To make this "probe" more sensitive, you can slide the small straw with the tiny magnet further out from the wooden stick. You can also move the tiny magnet up or down slightly within the hole in the small straw. Experiment to see how you can make the probe the most sensitive without having the tiny magnet stick to the sample magnet.
4. A refrigerator magnet can also be used as a sample. The straw with the magnet needs to be pulled out to make the lever arm longer and more flexible, and the tiny magnet must be adjusted downward so as to be very close to the refrigerator magnet in order to detect the weak magnetic field from the sample.

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CA Science Content Standards

Grade 5, Standard 1e – scanning probe microscopes
Grades 9-12, Physics Standard 5f – magnetic fields

Materials

- Scissors
- Red stripe stir straw (“small straw”)
- Drinking straw (“large straw”)
- Wooden stir stick
- Tiny rare earth magnet
- Toothpicks, round and narrow, 2
- CD type jewel cases, regular size, 2
- Bar or doughnut magnet
- Refrigerator magnet

Notes to the presenter

This probe is very sensitive to the distance between the probe (tiny) magnet and the sample magnet, especially when the two magnets are attracted. If the probe magnet keeps sticking to the sample magnet, have students turn the sample magnet over so the probe and sample will be repelled.

You can make the cantilever stiffer by pushing the small straw further into the large straw. You can adjust the distance between the cantilever and the sample by stacking the cantilever on another jewel case, by stacking the sample on another media tray, or by adjusting the position of the probe magnet in the hole in the small straw.

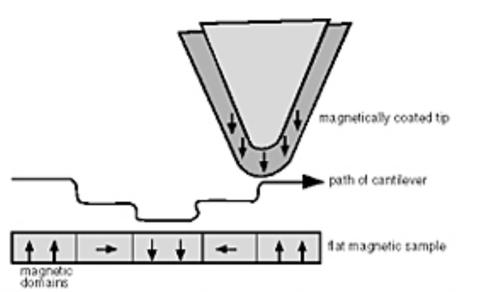
Probing a refrigerator magnet can reveal the interesting patterns in the magnetic poles. However, these magnetic fields are very weak, and this will require some patience to adjust the probe/sample separation to just the right distance. (This example can be used as an exercise in fine-tuning an engineering design.)

Videos of the assembly and usage of the Magnetic Force Microscope are available on the CPN website and YouTube.

What’s going on?

The magnet is a model for how a magnetic force microscope (MFM) works. It lets you “feel” something that you can’t see: in this case, a magnetic field.

MFMs use a super sharp tip to move across a nanoscale surface. (A nanometer is a billionth of a meter.) By dragging this tip around on magnetic surfaces and recording the strength of the magnetic attraction or repulsion, scientists are able to piece together a map of the magnetic domains in the material.



MFM maps the magnetic domains of the sample surface.

Extensions

You can engage students in other models of how scanning probe microscopes (SPMs) work:

- Ask students to close their eyes, make a fist, and run a finger tip over their knuckles. Their finger is a model for how an SPM tip moves over a surface, going up and down as it encounters nanometer-sized hills and valleys.
- Ask students to close their eyes and slowly move their index fingers across their faces, back and forth from top to bottom. Their finger is a model for how an SPM tip scans across a sample and detects changes in height and composition (skin vs hair).

You can engage students in further applications of magnets:

- An MFM uses the same basic technology as a computer hard drive. Binary data is encoded in the magnetic domains of the hard drive. The read head passes over these domains and senses the attraction ("1") or repulsion ("0") of each domain.
- For further activities related to magnets and hard drives, see "Probing What You Can't See" and "Exploring Forces with Magnets" in the CPN resource library.

You can use engage students in a discussion of the engineering of scientific instruments:

- Ask students gradually increase the distance between the probe and a given sample. Discuss how the sensitivity decreases with distance until the movement of the probe tip is no longer visible. Discuss the use of lasers and photoelectric detectors to measure tiny fluctuations in the position of the probe. Discuss the use of computers and piezo-electric materials to control the positions of the sample and the probe to within nanometers.

Credits

The Center for Probing the Nanoscale (CPN) at Stanford University is supported by the NSF under award PHY-0425897. For more information and other activities, visit http://cpn.stanford.edu.

This activity was created in cooperation with RAFT (Resource Area for Teaching).

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