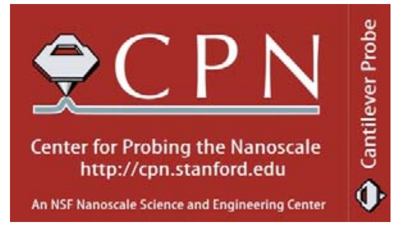
Probing What You Can't See

Investigating magnetic forces and poles using a refrigerator magnet.

Try this!



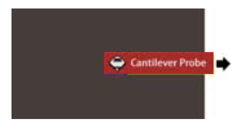
1. You probably already know that magnets have a north pole and a south pole. Look at the refrigerator magnet. Write a *prediction* of where you think the poles are on this magnet.

   ____

   ____

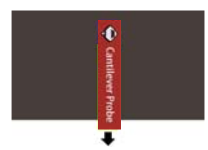
2. Since we can't see magnetic poles, we need a tool (a "probe") to help us learn about magnets. Remove the "cantilever probe" strip from the right side of the magnet.

3. Slowly pull the probe across the back side of the magnet from left to right. What do you feel?

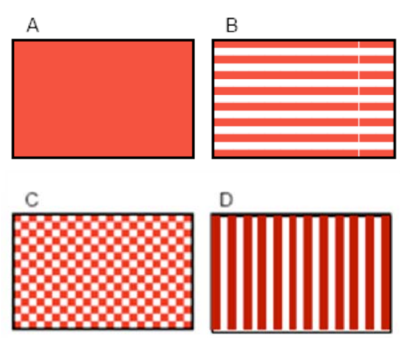
   ____

4. Now pull the probe across the back side of the magnet from top to bottom. What do you feel?

   ____

5. Based on your *observations*, explain which of the diagrams at the right best shows the way the magnetic poles are arranged on the refrigerator magnet.

   ____

   ____

   ____

6. Try using the probe on the printed (non-black) side of the magnet. What do your observations tell you about the magnetic poles on this side?

   ____

CA Science Content Standards

Grade 4, Standard 1f – magnetic poles
Grade 4, Standard 6a – differentiate observation from inference
Grade 5, Standard 1e – scanning probe microscopes
Grade 6, Standard 7e – recognize whether evidence is consistent with explanation
Grades 9-12, Physics Standard 5f – magnetic fields
Grades 9-12, Investigation & Experimentation Standard 1b – identify sources of uncertainty
Grades 9-12, Investigation & Experimentation Standard 1j – issues of statistical variability

Materials

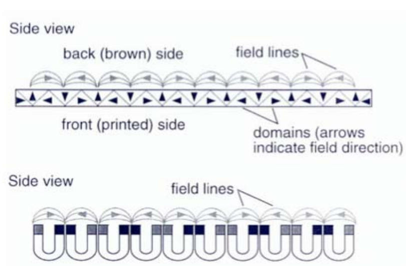
- CPN refrigerator magnets

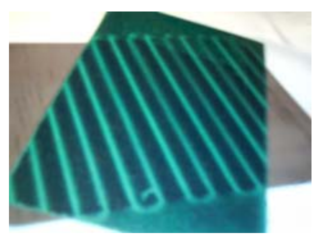
Notes to the presenter

You can do this activity with almost any flexible magnet, but the magnetic field may be oriented differently on each. To create a probe from an ordinary flat refrigerator magnet, cut 5-mm-wide strips from the side of the magnet and from the bottom of the magnet. Drag each strip across the magnet in both directions – vertically and horizontally – with the black side of the strip against the black side of the magnet. The strip that bounces should be used as the probe. Throw away the other strip.

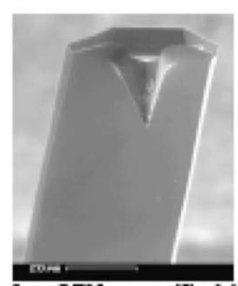
What's going on?

The magnet is a model for how a scanning probe microscope (SPM) works. It lets you "feel" something that you can't see: in this case, a magnetic field. The north and south poles run in alternating bands across the refrigerator magnet. You feel the strip bump across the surface when it's pulled across the bands because it's alternately attracted to and repelled by the poles it encounters. When the strip is pulled parallel to the bands, you don't feel the bumps because it's always attracted to the surface.





A scanning probe microscope similarly works by "feeling" something you can't see with your eyes. But in addition to detecting magnetic fields, an SPM can also detect lots of other things about a surface: nanometer-sized hills and valleys, atoms, electrical conductivity, friction, stiffness, and more.



Tip of an SPM, magnified 1000x

SPMs 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 different surfaces and recording the bumps and grooves, scientists are able to piece together what a surface looks like at the atomic level. Once scientists could make images of individual atoms, they could begin to study, manipulate and control things at this incredibly tiny scale.

Extensions

You can engage students in other models of how 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 inquiry into magnets:

- Ask students to experiment using the other side of the probe or the other side of the magnet. Neither of these will work because of the magnetic domains in the magnet and probe. In fact, the magnets will not stick to anything using the non-black side because the magnetic field is very weak on that side of the magnet, as shown in the diagram on the previous page.
- You can also visualize the magnetic fields of the refrigerator using iron filings. Seal the filings between two transparent pieces of plastic. Place this assembly over the magnet and shake gently. The iron filings will align with the magnetic field lines, and you should be able to clearly see the alternating strips. You can also make the magnetic fields visible to students using magnetic field film as shown in the image on the previous page.

You can use this activity to practice experimentation and discuss uncertainty and variability:

- Ask students to determine "how strong" the magnetic field from the magnet is. Have the students probe the magnet with a sheet of paper between the magnet and the probe. Add additional sheets of paper until the probe no longer bounces. Collect data from the class and discuss the varying results. Discuss the uncertainty of when the probe stops bouncing and the differences between individual magnets.
- For a more quantitative experiment, find a vertical metal surface to which the magnet will stick. Add sheets of paper between the magnet and the metal until the magnet falls. Collect data from the class and discuss the varying results. Discuss the differences between individual magnets and sheets of paper.

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 adapted from "Exploring Tools – SPM" from NISE Network, which was originally adapted from the "Quick Reference Activity Guide: Refrigerator Magnet," developed by the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at:
http://mrsec.wisc.edu/Edetc/supplies/ActivityGuides/Refrig_Magnet_Guide_2005.pdf
Image of refrigerator magnet structure from UW-Madison MRSEC. Image of magnetic field film from Zureks (Wikimedia Commons). Image of SPM tip by SecretDisc (Wikimedia Commons).

Permissions