Lesson Plan

Title: Probing Surfaces

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Students in AP Physics B do not get a good sense of the material differences that cause some of the properties that we study in physics. We study magnetism, refraction, heat transfer, conductivity and resistivity and they do not realize that the difference in the materials causes the differences in these properties. We do not do enough activities for magnetism. I have chosen to concentrate on magnetism and the differences in materials for this lesson.

Abstract:

This lesson is a modeling of Atomic Force Microscopy, or AFM. In this activity students use small magnets and bendable straws to probe a surface created by stronger magnets on the underside of a plastic container. They will have an image sketched by the end of the activity to compare with the real objects on the container. Once they have completed this activity the students will use several applets and websites to answer the research questions at the end of the activity. Students will produce a lab report on the activity that is graded using the rubric included here.

Alignment with National Standards:

AP Physics is controlled by CollegeBoard and has objectives we must meet. The AP Physics objectives covered in this activity will include the following:

D. 2. a. Students should understand the force exerted on a current carrying wire in a magnetic field so they can calculate the magnitude and direction of the force of a straight segment of current carrying wire in a uniform magnetic field.

E. 1. b. Students should understand ... Lenz’s law.

E. 1. c. Students should be able to analyze the forces that act on induced currents so they can determine the mechanical consequences of those forces.

Georgia State Physics Standards Alignment:

SP5. Students will evaluate relationships between electrical and magnetic forces.

Objectives:
The students should gain an understanding of microscopy.

The students will gain an understanding of the properties of materials that affect magnetism.

Anticipated Learner Outcomes:

Assessment/Rubrics:

Background:

Students have no concept of scale much less how difficult it is to analyze a surface that is small in scale. Atomic force microscopy, or AFM, is used to analyze surface structure on the order of nanometers. AFM uses a cantilever with a sharp tip at the end. When the tip is brought near a sample, forces between the tip and the sample cause deflection of the tip. The deflection is measured using a laser reflected off the top of the cantilever into an array of photodiodes. The resulting image is a topographical map of the surface of the sample.

Students have only used optical microscopes and thus have only been exposed to images on a larger scale. To observe the surface of a sample with steps of approximately 5 nm in height we must use some other means of observation. AFM provides the necessary resolution for this. My students are unable to do AFM, but I would like to simulate AFM for them with an activity.

Materials and Supplies: Opaque plastic container or cardboard box, bendable drinking straws, variety of magnets with a variety of strengths, tape, small magnet, paper, pencil

Teacher directions:

Turn the opaque plastic container so the bottom faces up. Tape a pattern of magnets and ferromagnetic materials to the bottom of the container. Be sure they will not fall off. Place them so that they will repel as well as attract the probe as the students try to determine the pattern. This serves as the “surface” the students will probe.

Take two bendable straws and tape them together, you may use one straw as well depending on the size of your probe magnet. Tape the small probe magnet to the end of the straw(s).

You will need a plastic container and a probe for each group of students. I would give each student a container and probe if you have enough supplies otherwise try to keep groups small.

Tell students not to flip the plastic container over until you tell them to do so.

Each group will need a blank piece of paper or a piece of graph paper to map the surface you have given them.

Student directions:

Your teacher will provide one “surface” to probe. You will need a probe, piece of paper, tape and pen or pencil.
Procedure:

1. Place your “surface” on your desk.
2. Tape a piece of graph paper to the surface. You will mark your findings on this piece of graph paper as you probe the surface.
3. Using your probe start at the lower left corner of the surface and move in a straight line parallel to the bottom of the surface toward the right.
4. Mark any forces you might notice as you probe. Record them on the graph paper. Use an x in the box for an attractive force and a dot for a repulsive force.
5. When you come to the end of the sample surface move up the surface the length of the probe magnet and move to the left in a straight line parallel to the bottom of the surface and repeat.
6. Continue until you have probed the entire surface.
7. Discuss the shape of the surface and what you think might be under the container with your lab partners.
8. Take your sheet of paper to your teacher and ask her how your scan compares with the actual arrangement.
9. If you are wrong try repeating the process to gain a better scan of your surface.
10. Once you have mastered this surface repeat with a different surface. You can trade with another lab group to get another surface to scan.

Questions:

1. How did the probe react to the surface?
2. What could this type of scan tell you? What was not obvious with this type of scan?
3. What would happen if your surface had smaller features? How would this affect your ability to scan with the probe you were given?
4. What would you predict to be the smallest scale object you could scan with this method?

Research Questions:

1. What is Atomic Force Microscopy (AFM)?
2. How does this compare to AFM?
3. Is there another type of microscopy that this activity might be closer to?
4. When you observed specimens under the light microscope in biology what size were the specimens you were looking at? What resolution did those microscopes have?
5. Can we use light microscopes for these types of surfaces?
6. Sketch a force diagram for the probe and surface in this activity.

Lab Report

Prepare a lab report with the following:

1. Title
2. Objective
The lab reports are graded using the following rubric. Each component is given a ranking from 1 to 5 with 5 being the highest ranking. The totals for each row are then added up and a total score is given out of 100 points.

**Lab Report Rubric**

**Principles and Theory**

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Explanation of the experiment  
5

Explanation of how the experiment was done
5

**Data**

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Data Tables are complete  
10

Data is labeled correctly  
5

**Calculations and Analysis**

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Results stated  
5

Compare results to reality  
5

Graphs  
5

**Conclusions**

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Stated accurate conclusions based on data  
Identified sources of error  
Further Research  
Answered all research questions  
Answers to research questions are correct  
Total Score  
Summary:

Students will gain a greater understanding of the difficulties of scanning surfaces with small features. They will be able to describe AFM and its uses when they conclude this activity.

Resources:

Students will be given this list of resources to aid them in their research as they answer the questions from the lab.

http://www.youtube.com/watch?v=4fSyYaFGlUJ
Video about AFM and its limitations

http://chaosbook.org/projects/Kasivajhula/index.html
AFM java applet

http://www.chembio.uoguelph.ca/educmat/chm729/afm/firstpag.htm
AFM introduction

http://virtual.itg.uiuc.edu/training/AFM_tutorial/
Probing microscopy video tutorial including STM and AFM

http://www.nature.com/nchem/journal/v4/n6/compound/nchem.1332_comp1_3d.html
This applet lets you manipulate images of molecules to see surfaces using different forces