Mysteries_of_Magnetism_

PROFESSOR GARBER: Hello. My name is Gary Garber, and I teach science at Boston University Academy in Boston, Massachusetts. We are here at the technology enabled active learning laboratory at the Massachusetts Institute of Technology in Cambridge, Massachusetts. What you were looking at right now is an example of magnetic levitation using supercooled superconducters.

Over 2000 years ago, Thales of Greece was the first to record the effects of magnetism. He discovered mechanism in rocks that he collected from the town of Magnesia. Just how does magnetism work in these rocks? What is the source of magnetism?

Your teacher will now provide you with magnets, iron filings, paper clips, and compasses. Working in small groups, explore how magnets work. How do the magnets affect each other? The iron filings? The compasses? And other objects your teacher might give you. What do you need to do in order to see the magnetic phenomena? Draw sketches to express your ideas about magnetism. Compare your ideas of magnetism to the electric force or to the gravitational force.

We'll pause now while you explore the mysteries of magnetism.

Welcome back. In your exploration of magnetism, you may have noticed that magnets can affect things at a distance. You may have noticed that there are two sources of magnetism, north poles and south poles. So what is happening inside a magnet? What are these poles?

Here I have the north pole of my magnet repels and the south pole attracts. But what happens if I break this magnet in half? Should one piece be a north pole and the other piece be a south pole? Let's look and find out. This is a north pole, but it also has a south pole. This piece has a south pole, but it also has a north pole. Both pieces have a north and a south pole.

You may have noticed before that you can magnetize the paper clips. If we expose a piece of iron to a strong magnetic field, it becomes magnetized. The paper clip now has a north pole and a south pole. However, if you heat a magnet, it loses its magnetism. I will now heat this magnetized paper clip. I will now cool it off in water. Observe, it is no longer magnetic. Why is this?

Additionally, if a magnet is exposed to extreme shock, it loses its magnetism. Observe, it is no longer magnetic. In this next activity, you will use a magnet made from a straw and iron filings. How can you magnetize this straw magnet? How can you destroy the magnetism of the straw magnet? What ideas does this give you about how magnetism works? Sketch your ideas. Discuss your ideas with your neighbors. We'll be back in a moment.

Welcome back. You may have noticed that you can magnetize this straw by stroking it with the magnets. The straw was filled with hundreds of small iron filings and each iron filing was a tiny little magnet. Each iron filing has its own north and south pole. When we expose the straw to a strong magnet, all of the tiny iron filings line up. Our entire straw is now magnetized.

The same thing actually happens to a piece of iron. Our paper clip actually contains tiny microscopic magnets, which we call domains. Each domain has its own north and south pole. When we expose our paper clip to a strong magnetic field, all of the domains lineup.

You may have noticed that not only could you magnetize the straw, but if you shook the straw, it would lose its magnetism. This is because all the iron filings in the straw are no longer lined up. This is much harder to do in a real bar magnet or a paper clip. Striking the paper clip with a hammer was similar to shaking the straw.

Similarly, when I heated the paper clip in the flame, as the paper clip got hot, the molecules started to vibrate more. These molecular motions disrupted the domains in my paper clip. The temperature at which an object loses its magnetism is called the Curie Point.

Pierre Curie discovered that above a certain temperature, pieces of iron would lose their magnetism. But what are domains? We'll come back to this mystery later in the lesson.

Another mystery of magnetism is how can magnets affect things at a distance? Michael Faraday came up with the concept of a magnetic field to explain this action at a distance. You can conceptualize these field lines like spider webs emanating from one pole of the magnet and going to another pole. Here, we can see these field lines seem to fill the space surrounding a magnet. I have iron filings that are sprinkled in the area around a magnet, and they line up with the field lines.

You are now going to sketch what the magnetic fields look like. You can actually use compasses to try and map these field lines, or you could use iron filings to map the magnetic field. Let's take a break and sketch what the fields of magnets look like. Compare your results to that of your fellow students.

How did it go? In your experimentation you should have seen what the fields of magnets look like. The field lines leave the north pole of the magnet and go to the south pole of the magnet, as you see in this simulation. You should have seen the iron filings line up along these field lines. Also, the compasses align themselves along these field lines.

Bar magnets are not the only source of magnets in our daily lives. In fact, you might find that you are surrounded by electromagnets. These are magnets that are created by sending electricity through a coil of wire. Here, we can see many examples of electromagnets. In this bell, the electromagnet pulls the clapper back. In this crane, the electromagnet picks up paper clips. In this rocket launcher, the electromagnetic pulls back a spring to launch the rocket. And in this toy train car, an electromagnet ejects the mail.

But how do electromagnets work? How are they similar or different from natural magnets? What does the field of an electromagnet look like? You can create an electromagnet by coiling wire around a cardboard tube or a steel bolt. Let's take a break and do some experimentation with electromagnets. Take your coils and some compasses, and let's map the fields of electromagnets. Put your compasses above the coils, or below the coils, or inside the coils, and try and draw sketches of the field of an electromagnet.

Welcome back. In your experimentation, you should have seen many similarities between the field of an electromagnet and the field of a natural magnet. In this simulation, you can see what the field of an electromagnet looks like. The electromagnetic has both a north pole and a south pole. Outside of the coil, the field lines leave the north pole and go to the south pole. This is similar to what you may have seen with the natural magnets. You may have also placed compasses or iron filings inside of your electromagnet. If you did this, you may have noticed that inside the coil the magnetic field lines actually point in the opposite direction.

Hans Christian Oersted first investigated electromagnetism when a single wire carrying a current was placed near a compass. Here we can see a compass being deflected when we turn on the current in a wire above the compass. But what does the field of a single wire look like? Here I have iron filings surrounding a wire carrying a current. Watch what happens to the iron filings when I turn on the electricity?

What would happen if I were to take this wire and wrap it around a box? What would the magnetic field look like? What if I were to take a wire and wrap it around this tube? What would the magnetic field look like? Let's take a break and discuss with your fellow students what does the magnetic field of a single wire look like?

What does the magnetic field of a loop look like? What is the connection between them? How does the magnetic field of a single wire give rise to the magnetic field of a loop? Use diagrams and sketches to express your ideas.

Welcome back. You probably realize that the magnetic field of a single wire follows concentric circles. Earlier in the lesson, you realized that the magnetic field of a loop goes in one direction outside of the loop and in the other direction inside of the loop. The connection between a single wire and a loop is a simple matter of geometry. You may have seen what happens as we bend the wire into a square around a box. Assume the magnetic field always encircles the wire.

During this segment of our wire, the magnetic field goes this way outside of the loop and in the other direction inside the loop. Look what happens in the next segment of our wire. The same thing. Inside of the loop, the magnetic field points in one direction and outside in the other. This continues for every segment. If we expand what we know about the magnetic field of loops to a coil, a coil contains many loops and thus has a very strong magnetic field.

Now, what causes the magnetic field in rocks? Consider this. Rocks contain millions and millions of domains. Each domain is a very tiny little magnet. The source of magnetism is electricity or current traveling in loops, and the magnetic field of a coil is very similar to the magnetic field of a bar magnet. Now, discuss with your fellow students what is the source of magnetism in the rocks that Thales discovered in Magnesia?

Welcome back. Today, we have explored many of the mysteries behind magnetism. Since the source of all magnetism is moving charges, you may have realized that natural magnets must contain moving charges. These moving charges happen to be related to the motions of the electrons in atoms. You probably know that electrons orbit the nucleus.

Also, there's a property of electrons called spin that is related to the phenomena of magnetism. Without delving further into the world of atomic physics, we can say that the source of magnetism in natural magnets is the motion of charges on the smallest level. I hope you enjoyed today's lesson. There are many mysteries of magnetism that we have yet to discover. The next time you go outside, think about which way is north. Think about the Earth's magnetic field, which has many mysteries that maybe you will someday explain to us.

Hello. This is Gary Garber, and this is the teacher's video guide to the lesson The Mystery of Magnets. You will find that the written guide will help you step-by-step through the video segments and the activities and discussions that go with each segment. Along with some suggestions of what the students should learn in your class prior to doing each lesson. During this short video guide, I will give you an overview of the lesson and its activities and point you to further resources that will help you explore the topic with your students during other class sessions.

In this lesson, students will develop the ideas behind the sources of magnetism in natural objects. I have designed this lesson so that you will not need specific materials and can adapt the experimentation to the materials you have available to you. When I do experiments with my own students, I actually like to supply them with a variety of equipment and let them play a role in designing the experiment.

In fact, I often will not supply enough redundant material or equipment to force some variation in the way that students design their experiments. This leads to richer discussions and a wide variation of results. It also allows it to be OK that students can produce different results from their experiments and engage in collaborative joint sensemaking.

They will begin this lesson by exploring how magnetism behaves. In the first activity, they will develop their ideas about magnets by playing with magnets, iron filings, and compasses. They will then explore the ideas of magnetic domains using straws filled with iron filings. You can make these straws for the students in advance, but if you have time, the students may enjoy making their own straw magnets.

In the third activity, the students will develop and map field lines of natural magnets using compasses and/or iron filings. In the fourth activity, the students will map the fields for electromagnets. You could use either batteries or plug-in power supplies to power the electromagnets. In the fifth break, students will draw and conceptualize the abstract connections between the field of a single wire and the field of a loop.

In the sixth break, the students should synthesize their experiences from the lesson and try to explain the connections between magnetism and natural objects and electromagnetism, and thus, explain the mysteries of magnetism. You will find that I use many computer simulations in this video. I have provided links to all of these computer simulations in the written teacher's guide, and I find great benefit in letting my students play around with these simulations.

One of the key things I hope you enjoy with this lesson is having the students actually have discussions. That's one of the benefits in this room that we're in right now. The teacher enabled active learning laboratory is a focus on having students discuss and explore ideas in science.