Lesson: What's Magnetic?

Teacher Section

Overview Students will grab a magnet and move around the room trying to figure out what's special about the objects that stick to it. There are two data sheets they will fill out in their quest.

Suggested Time 30-45 minutes

Objectives To discover not only what's magnetic, but also what specific kinds of objects are magnetic. Magnetic fields are created by electrons moving in the same direction. Electrons can have a "left" or "right" spin. If an atom has more electrons spinning in one direction than in the other, that atom has a magnetic field. If an object is filled with atoms that have an abundance of electrons spinning in the same direction, and if those atoms are lined up in the same direction, that object will have a magnetic force.

Materials (per lab group)

- *1 rectangular magnet*
- *1 circular disk magnet*

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the *Background Lesson Reading* before teaching this class.
3. Identify several dozen objects in your room that are magnetic so you are prepared with the kids need a little help.

Background Lesson Reading

What Causes Magnetism? Believe it or not, electrons! Those wacky little fellows that we learned about several lessons ago are the key to magnetism. As you move further and further in your science education, you'll notice that electrons are responsible for a lot of stuff that goes on in science!

More accurately, a majority of electrons moving in a similar direction creates a magnetic field. This is how electromagnets work. Electrons are forced to move through a wire and the moving electrons cause a magnetic field. (We'll look deeper into magnetic fields in a future lesson.)

"But how are electrons moving in my magnet on my fridge? It isn't connected to any battery. What's going on there!? Don't I need electricity to have moving electrons?"

Electromagnets do have electricity flowing through them. Electricity is nothing more than moving electrons. So it's the electricity that causes the magnetic force in electromagnets.

However, most of the magnets you run across are not attached to any form of electricity. So how are the electrons moving?

Electrons move on their own. They move around the nucleus and they spin. It's the electron spin that tends to be responsible for the magnetic field in those "permanent" magnets (the magnets that maintain a magnetic field without electricity flowing).

"But don't electrons always spin? Shouldn't everything be magnetic?"

Yes, electrons are always spinning. The reason some things are magnetic and other things aren't is due to the balance of the spinning electrons.

Electrons are said to spin left or right. It not quite that simple but it makes it easier to think and talk about. Most atoms have a fairly even number of left and right spinning atoms. If there's four spinning left, there's four spinning right. If there's nine spinning right, there's eight spinning left. Since they are fairly balanced, there's no net direction that the electrons are moving in. With no overall direction of movement there's no magnetic force.

However, there are a few atoms, iron being the most famous, that are not in balance. Iron has four more electrons that spin in one direction than in the other. This excess of same spinning electrons creates a net directional movement and thus, a magnetic force! Nickel and Cobalt are other fairly common magnetic metals.

"Aha, so everything that's made of iron is magnetic! Got it."

Well, not so fast. Yes, each iron atom is like a little magnet but not all iron objects have a magnetic field. In fact, most don't. The reason that most objects that have iron in them are not magnetic is because the atoms are all jumbled up.

Imagine I gave you a shoe box filled with small magnets. Since I just threw the magnets in there, they are all jumbled up. Some are facing right, some left, some up and some down. Because of the jumble, the whole box may not have much magnetic force since the magnets inside are all canceling each other out.

Now, imagine what would happen if the magnets inside the box did all face the same way. If I stuck them all end to end and created a long string of magnets. Now the box would have a very powerful magnetic force, right? This is the difference between an iron nail and a magnet. The nail has iron atoms going all which ways, while the magnet has iron atoms that are fairly lined up. The more lined up the iron atoms are, the stronger the magnetic force.

Diamagnetic materials (like bismuth, water, and graphite) have very weak magnetic fields. When the electrons have about the same number spinning left and spinning right, they cancel each other out and the atom has no magnetic poles. However, if you bring a magnet near, the magnetic field causes the individual electrons in the atom to move, and since moving electrons create a magnetic fields, the electrons create a magnetic field opposite to the original magnetic field and the atom moves away from the magnet. The effect is very weak, but with enough care you can see this effect in water (which is what a grape is mostly made up of).

Paramagnetic materials (like aluminum, helium, and platinum) need to be chilled in order for their magnetic fields to be noticeable. Here's why: what if the atom has more electrons spinning left than right? When this happens, the atom now has magnetic poles (north and south), and you can think of each atom like a little magnet. However, these magnets are not all lined up in the same direction, so their overall magnetic effect cancels out. If you bring in a magnet (or place the atoms in a magnetic field), they start to line up in the same direction and the material starts to become magnetized. But not quickly, or easily, because the atoms still have so much energy that they keep bouncing around, even when in a solid state. So to magnetize something quickly, you need to bring down the temperature to reduce the motion of the atoms to start them to really line up. Paramagnetic materials are attracted to both ends of a magnet.

Ferromagnetic materials are the four elements (iron, nickel, cobalt, and gadolinium) that most permanent magnets are made up of. These atoms stay lined up together, even when they are at a temperatures that would cause other atoms to bounce out of alignment. The magnetic effects are mostly caused by the innermost electrons in the inner orbits, which all aligned the same way, and contribute the magnetic field. Some paramagnetic materials (like chromium and manganese) have atoms pair up and cancel each other out. The north pole of one atom will line up with the south pole of another.

Lesson

1. While the kids are filing in, write this on the board:

    I stick to some things but not to others.
    I stick but I'm not sticky.
    I attract some things, but push other things away.
    If allowed to move, I will always point the same way.
    What am I?

2. Well, since you know the topic of this lesson this isn't the hardest riddle to solve. "I'm" a magnet right? Sure. Tell the kids that today we're going to take a look at the wacky things a magnet does: It sticks but it's not sticky. It only sticks to certain things, and it pushes some things away. If you hang it from a string or float it in water, it will always point north. If that's not enough strangeness, as we'll find out in a later lesson, magnets can actually create electricity. Wow, what a wacky thing a magnet is!
3. Ask the kids: "*What is a magnet?"* Start the kids off by asking them where they think magnetism comes from in the form of a discussion. You can spark their imaginations by asking these questions:
    a. Why does a magnet stick to your fridge and not your soda can, even though both are metal? (The can is actually paramagnetic, which we will talk more about later.)
    b. Are all magnets made of metal? (Some are ceramic or bendy like plastic.)
    c. The breakfast they ate this morning was probably also magnetic… what do they think it was? (Cereal fortified with iron. Watch the video and demo this effect. You can have the kids do this at home for homework for tomorrow.)
4. Announce to the kids that today they are going to be magnetic detectives as you the lab. Their job is to find what kinds of objects are magnetic.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups. Hand each group their materials.
2. Have the kids run around the room with their magnets and test several different objects to see if the magnet sticks to it. The kids will fill out their data sheet as they go along, or do it after they race around testing different objects (your choice).
3. After they've completed the first data table, ask for shares. What did they find that is magnetic? Write down their answers on the board in a list for everyone to see. You should not have any items that are not metal in your list.
4. Ask them to test the materials on the list and identify what kind of metal it is. They will write this in the second data table. In your classroom, you should be able to find brass, tin, aluminum, silver, gold (if you're wearing jewelry and they are careful), steel, iron, tin… etc.
5. Regroup and ask the kids if there's a pattern. What kinds of metal are magnetic? (You should only find that iron, nickel, and cobalt are magnetic.)

Exercises

1. Which objects are attracted to the magnet? (Objects containing iron, nickel, cobalt, or gadolinium)
2. Are all metal objects attracted to the magnet? (No. See #1 above)
3. Does the shape of the magnet matter? (No, but we'll explore where the poles are on different magnets next time.)

4. Are things attracted to the magnet if they have to pass through something that isn't, like a piece of paper? (Yes – magnetic force can travel through materials that are not attracted to the magnet.)

Closure Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.