KANSAS CITY PUBLIC SCHOOLS

The lab of MR.Q

KCMO PD Workshops - Scott McQuerry

2012-2013

Magnetizing Marvels and Electrical Explanations

SP SCIENCE PIONEERS

Push me a grape

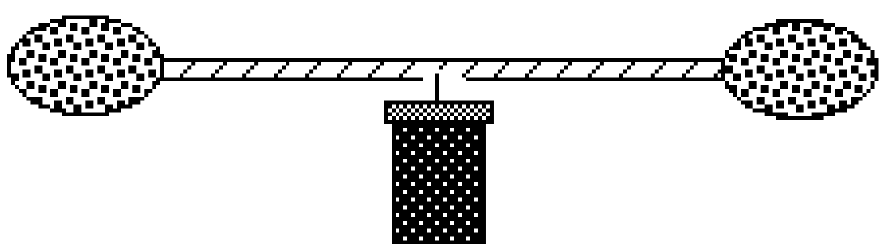
A grape is repelled by both the north and south poles of a strong rare-earth magnet. The grape is repelled because it contains water, which is diamagnetic. Diamagnetic materials are repelled by magnetic poles.

Materials

Two large grapes
Drinking straw
Film canister with lid
Push pin
Small knife or razor blade
Neodymium magnet

What to do:

Insert the push pin through the underside of the film canister lid and put the lid on the canister so that the point of the pin is sticking out.
Find the center of the drinking straw and use the knife to cut a small hole, approximately 0.5 cm x 1 cm. (You can also use the hot tip of a soldering gun to melt a hole.)
Push one grape onto each end of the straw. Balance the straw with the grapes on the point of the push pin; the point of the pin goes through the small hole on the straw.



side view

Bring one pole of the magnet near the grape. Do not touch the grape with the magnet. The grape will be repelled by the magnet and begin to move slowly away from the magnet.
Pull the magnet away and let the grape stop its motion.
Turn the magnet over and bring the other pole near the grape. The grape will also be repelled by the other pole; the grape is repelled by both poles of the magnet.

What's going on?

Ferromagnetic materials, such as iron, are strongly attracted to both poles of a magnet. **Paramagnetic materials**, such as aluminum, are weakly attracted to both poles of a magnet. **Diamagnetic materials**, however, are **repelled** by both poles of a magnet. The diamagnetic force of repulsion is very weak (a hundred thousand times weaker than the ferromagnetic force of attraction). Water, the main component of grapes, is diamagnetic.

When an electric charge moves, a magnetic field is created. Every electron is therefore a very tiny magnet, because electrons carry charge and they spin. Additionally, the motion of an orbital electron is an electric current, with an accompanying magnetic field.

In atoms of iron, cobalt, and nickel, electrons in one atom will align with electrons in neighboring atoms, making regions called domains, with very strong magnetization. These materials are ferromagnetic, and are strongly attracted to magnetic poles.

Atoms and molecules that have single, unpaired electrons are paramagnetic. Electrons in these materials orient in a magnetic field so that they will be weakly attracted to magnetic poles. Hydrogen, lithium, and liquid oxygen are examples of paramagnetic substances.

Atoms and molecules in which all of the electrons are paired with electrons of opposite spin, and in which the orbital currents are zero, are diamagnetic. Helium, bismuth, and water are examples of diamagnetic substances.

If a magnet is brought toward a diamagnetic material, it will generate orbital electric currents in the atoms and molecules of the material. The magnetic fields associated with these orbital currents will be oriented such that they repelled by the approaching magnet.

* Thank you Paul Doherty for this idea!

Terra Bagga Activity Using a Magnetometer

Students will build a simulated planet with a magnetic field. They will use a simple magnetometer to determine the orientation of the "planet's" magnetic field.

Materials

1 paper grocery bag made from recycled materials (these bags will break
down the best) • one plastic grocery bag (optional)
1 dead D-size battery
2 ceramic donut magnets, 1 and 1/8 inch in diameter
masking tape
3 rubber bands
Marker or thick pen
Magnetometer instrument (instructions provided at the end of this activity)

What to do:

1) You may wish to demonstrate the process of building a "planet" and finding the orientation of its magnetic field to your students first, and then having them do the process themselves.
2) The first step in building a "planet" with a magnetic field in it is to create the dipolar magnet that will go inside the world. Take the two magnets and place them on top of each other so that the magnets are attracted to each other. Now without flipping either magnet over, place the top magnet on the top of the battery. Tape this magnet in place. Place the bottom magnet on the bottom of the battery (remember, the side that was facing up,should now be against the casing of the battery). Tape this magnet in place.
3) Next turn the paper bag inside out. This creates a clean surface that will be labeled later on. Work the bag by crumpling it and folding it.
4) When the bag is turned inside out and is pretty workable, place your battery (with the magnets taped on) inside the paper bag. It does not matter which way the battery is facing. Work the paper bag around the battery to create

a nice smooth (fairly round) world. Try to center the battery/magnet in the middle of the "planet". If one pole is too close to the surface, the opposite pole may be buried too deeply to sense with the magnetometer. You may wish to use the optional plastic bag to add extra padding to the "planet's" interior to help center the magnetic core, or you may want to "double-bag" the "core" to accomplish the same result (i.e. first wrap the plastic bag around the "core", then surround both with the paper bag).

5) Use a generous amount of tape to hold your world together.
6) Using a magnetometer (see instructions below) test where the magnetic north pole of the world is located. The magnetometer end labeled north should dramatically point in where the magnetic north pole of their world is. Have the students write the segment number where they find the magnetic north pole of their world onto their student worksheet. Have them follow a similar process to locate the magnetic south pole of their "planet".
7) Have student groups trade planets. Students should use their magnetometers to locate the north and south magnetic poles for several planets and record that information on their student worksheets.

Magnetometer Construction

Students will build an instrument capable of detecting a magnetic field and magnetic polarity.

Materials:

10 cm (4-inch) long piece of plastic straw
2 steel straight pins
masking tape
sewing thread
magnet

What to do:

Place a small piece (about 4 cm [1.5 inches] long) of masking tape on your desk with the sticky side up.
Lay one pin across the tape (see Step 1 in Figure 1).

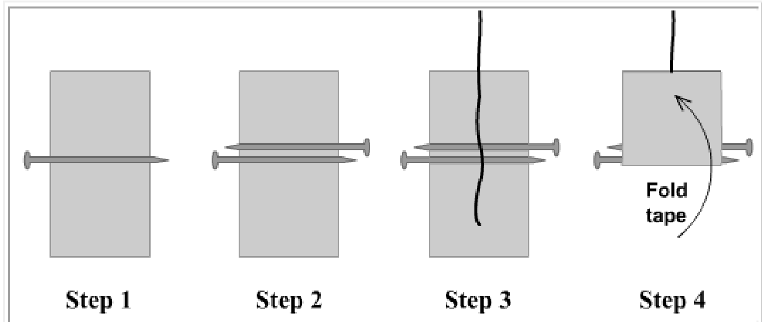


Figure 1

Lay the second pin right next to the first, but with the point in the opposite direction (Figure 1, Step 2). The idea is to have the heads of the pins protrude a bit on each side to make it harder to stab oneself with the points.

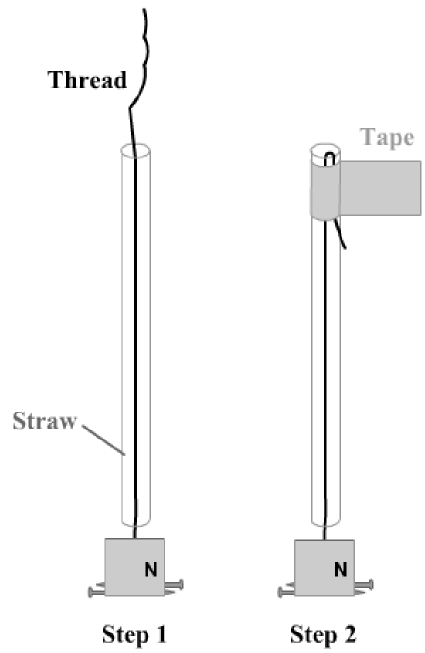


Figure 2

Lay one end of the thread across the pins and tape, running perpendicular to the pins (Figure 1, Step 3).

Fold the tape over the pins and end of the thread, with the crease in the tape at the pins (Figure 1, Step 4).

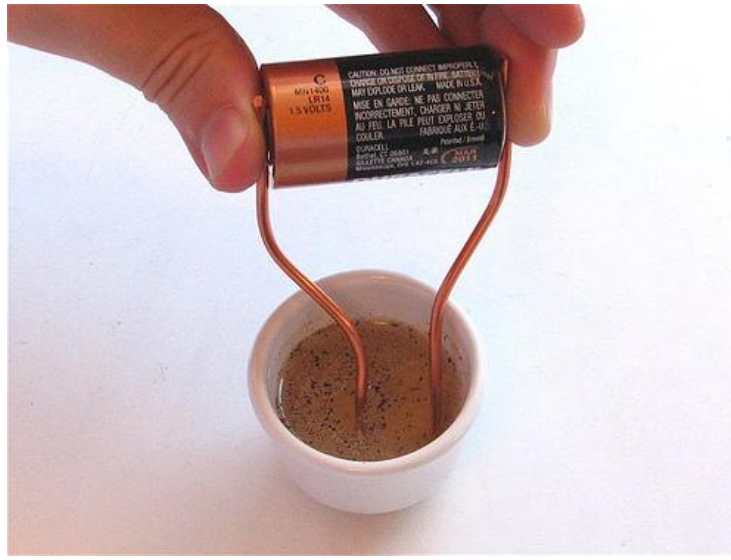
Push the thread through the straw. Hold the straw upright (its length should be vertical) with the taped pins dangling just below the bottom of the straw. The top of the tape holding the pins should be just below (about 2-3 mm or 1/4 inch) the bottom of the straw without touching it. The taped pins should be able to spin freely on the thread (see Step 1 in Figure 2).

Fold the top of the thread over onto the outside of the top of the straw, then tape it into place there (Figure 2 Step 2). Leave a little tab of tape sticking out - this can be used for students to write their names or group names on.
Stroke the pins (lengthwise along the pins) from left to right several times with one pole of a permanent magnet. This will magnetize the pins.
Hold the straw upright with the pins dangling beneath. Move the north pole of the magnet near the pins. One end of the pins will point towards the north end of the magnet (just like a compass does). This is the north-seeking end of your magnetometer. Label this north-seeking end by writing a small "N" on north-seeking end of the tape holding the pins.

What's going on?

Magnetic fields are invisible; we can only see the effects of the magnetic force. Magnetometers are devices used to detect and measure the strength of magnetic fields. Compasses are basically magnetometers with directions marked on them. A magnetometer will dip or point toward a source of magnetism. Have students use their magnetometer to find things in your room or at home that are magnetic.

Magnetohydrodynamic Propulsion



Materials:
Salt and pepper,
One Dixie cup
Two pieces of thick-gauge copper wire
A battery (just about any type)
A strong magnet (neodymium)

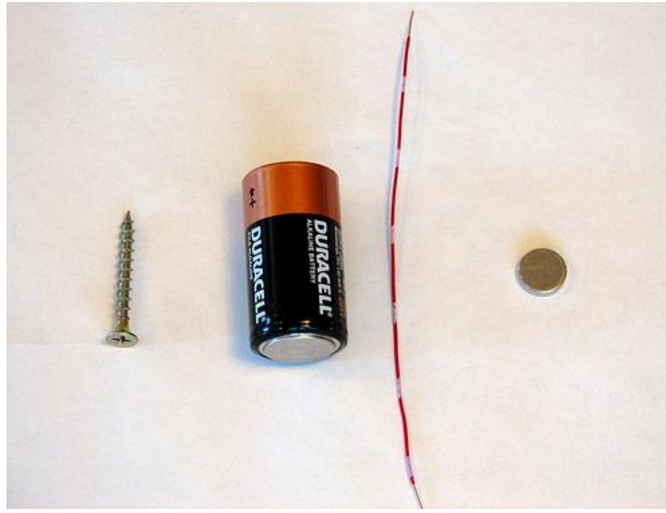
What to do:
Pour a little water in the dish and stir in some salt and pepper. The ideal depth of the water is about 1/4", but it's not critical.
Mix up the water so that the pepper doesn't all float on the top. .
Set the cup on top of your magnet.
Bend the wires as shown, so that when you hold the wires against the battery, the ends are a couple of centimeters apart. Don't let the two wires touch!
Stick the ends of the wires into the water. Ideally, put one wire in the center and one against the edge. Assuming that your battery isn't dead, the water will begin to move between the two wires. If you flip the magnet upside down or reverse the direction of current, it will reverse the direction that the water moves.

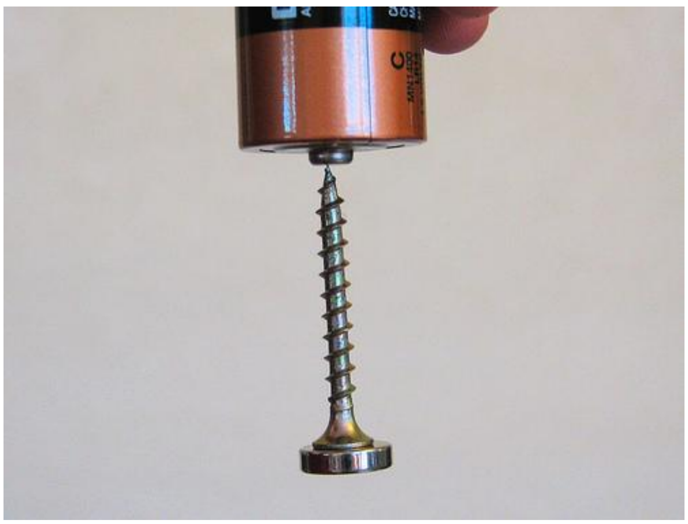
What's going on?
MHD propulsion relies on conducting current through water. Water is normally a poor conductor, but salt water is a great conductor. Adding the final dash of pepper makes it so that you can *see* when the water moves. If you are looking for a more detailed explanation, check out what's going on within the next activity: A Simple Motor

A Simple Motor

Materials:

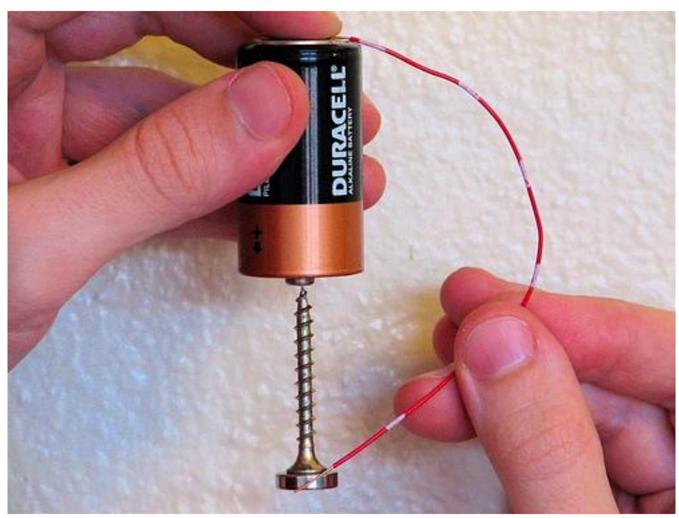
One drywall screw
One 1.5 V alkaline battery
Six inches of plain copper wire
One small neodymium magnet





Set the screw on the magnet, bend the wire.

Attach the magnet to one end of the battery.



How does this work?

The easy explanation:

When you touch the wire to the side of the magnet you create an electric circuit. A current runs out of the battery, down the screw, through the magnet, the wire and finally to the other end of the battery. The force of the magnet and the electric current flowing through it cause a new force to act on the magnet. this new force drives the magnet to spin very fast! Congratulations! You have must made a homopolar motor!

The "not so" easy explanation:

When you touch the wire to the side of the magnet, you complete an electric circuit. Current flows out of the battery, down the screw, sideways through the magnet to the wire, and through the wire to the other end of the battery. The magnetic field from the magnet is oriented through its flat faces, so it is parallel to the magnet's axis of symmetry. Electric current flows through the magnet (on average) in the direction from the center of the magnet to the edge, so it flows in the radial direction, perpendicular to the magnet's axis of symmetry. If you took physics at some point, it's possible that you'll remember the effect that a magnetic field has on moving electric charges: they experience a force that is perpendicular to both their direction of movement and the magnetic field. Since the field is along the symmetry axis of the magnet and the charges are moving radially outward from that axis, the force is in the tangential direction, and so the magnet begins to spin.

Voltaic Pile Activity

Materials:

Pennies
Nickels
Paper towels
Salt solution
Water cups
Multitester

What to do:

Tear paper towels into squares or circles that are slightly larger than the pennies, and submerge them in the salt solution.
Place a penny on the table, then a paper towel on the penny, then another penny, then another paper towel, etc.
Measure the electric potential with a multitester between the top penny and the bottom penny and record.
Begin with 2 pennies, and add one penny for each measurement until you reach 5-10 pennies. Continue with as many coins as you prefer. Try a variety of procedures to get the largest voltage out of your "battery."

What's going on?

In 1791, Italian scientist Allesandro Volta produced continuous electric current when he placed a cloth soaked in salt water between silver and zinc disks. In 1800, Volta discovered that the current increased when he stacked several pairs of these single electrochemical cells together. This device became known as the voltaic pile, and was the first electrochemical battery.

Although Volta used silver and zinc, it is more feasible – and inexpensive – to use copper and zinc for the metal disks. Even though pennies are no longer made of copper, their copper coating still makes them a great choice for copper disks, and zinc disks can be obtained by purchasing galvanized electrical boxes and punching out the holes.

Tesla coil

A fluorescent light bulb held near a Tesla coil will light up and spark, even without being plugged in!

Materials:

Handheld Tesla coil
Fluorescent light bulb

What to do:

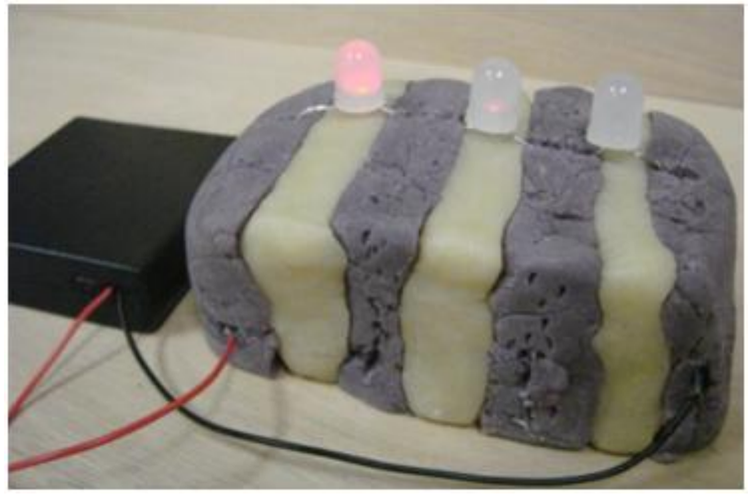
Plug in the Tesla coil and hold it near the fluorescent light bulb.
Turn on the coil and watch the bulb light up.

What's going on?

A Tesla coil is a device for making very high voltages. Voltage is a way to measure how much energy an electric charge has. Tesla coil can make voltages of more than a million volts. The small one used in the demonstration makes about 60,000 volts. Normally, such high voltages are very dangerous, but the Tesla coil makes very high frequency electricity. This means the coil turns on and off very quickly so they electricity flows on the outside of your skin instead of through your body.

The Tesla coil creates an electric field that pushes electrons through the light bulb. This is the same way the lights in your house work, except in your house, the electricity comes through a wire instead of through the air.

Squishy Circuits



How to make conductive dough:

Materials:

1 cup water
1 1/2 cups flour
1/4 cup salt
2 Tbsp. cream of tartar
1 Tbsp. vegetable oil
Food coloring (optional)

What to do:

1) Mix water, 1 cup of flour, salt, cream of tartar, vegetable oil and food coloring in a medium sized pot.
2) Cook over medium heat and stir continuously.
3) The mixture will begin to boil and start to get chunky.
4) Keep stirring the mixture until it forms a ball in the center of the pot.
5) Once the ball forms, place it on a lightly floured surface.

   WARNING: The ball will be very hot. I suggest flattening it out and letting in cool for a couple of minutes before handling.

6) Slowly knead the remaining flour into the ball until you've reached a desired consistency.
7) Store in an airtight container or plastic bag. While in the bag, water from the dough will create condensation. This is normal. Just knead the dough after removing it from the bag, and it will be as good as new. If stored properly, the dough should keep for several weeks.

How to make insulating dough:

Materials:

1.5 cups flour
1/2 cup sugar
3 Tbsp. vegetable oil
1 tsp. granulated alum (optional - the alum helps preserve the dough.)
1/2 cup deionized (or distilled) water

What to do:

1) Mix solid ingredients and oil in a pot or large bowl, setting aside 1/2 cup flour to be used later.
2) Mix with this mixture a small amount of deionized or distilled water (about 1 Tbsp.) and stir.
3) Repeat this step until the mixture absorbs a majority of the water.
4) Once your mixture is at the consistency as shown below, knead the mixture into one "lump".

5) Knead more water into the dough until it has a sticky, dough-like texture.
6) Now, knead the remaining 1/2 cup of flour into the dough, until a desired texture is reached.
7) Store in an airtight container or plastic bag. While in the bag, water from the dough will create condensation. This is normal. Just knead the dough after removing it from the bag, and it will be as good as new. If stored properly, the dough should keep for several weeks.

<u>What to do with all this dough</u>:

Materials for each group or child making circuits:

One 9V battery
A battery connector with spades or probes at the end of the wires (this can be accomplished using paper clips)
Conductive and Insulating dough
Several LEDs

How to make the circuits:

1) If your battery connector doesn't have large contacts at the end of the wires you will need to attach large contacts to the end of the wires. These can be either long metal probes or spades of some type.
2) Place your battery or batteries into the battery connector. Make sure you don't touch the battery contacts on the ends of the wire to each other, as this will cause a short.

3) Distribute conductive and insulating dough to the students. You will need more conductive dough than non-conductive. Students tend to like to work with more dough, but a ball the size of your fist is more than enough of either type.
4) Have the students divide the conductive dough into two pieces and roll these pieces into cylinders no thinner than one inch. Have them also roll the non-conductive dough into a slightly thicker cylinder.
5) Place the non-conductive dough cylinder between the two conductive playdough cylinders.
6) Push one battery contact into one of the conductive cylinders and push the other into the other conductive cylinder. Make sure the two pieces of conductive dough are not touching each other, as this will cause a short. Your students now have power connected to one of your cylinders of conductive dough, and a ground connected to the other.
7) Place one end of an LED into one of the conductive pieces of dough and the other end to the second piece of conductive dough. The LED should light up. If it does not, simply reverse the LED and the circuit should work!
8) When you are done with Squishy Circuit make sure you clean off the metal parts of the components and battery connectors with a damp paper towel because otherwise the salt will cause the contacts to corrode.

Check out the official Squishy Circuits homepage at:
http://courseweb.stthomas.edu/apthomas/SquishyCircuits/buildingCircuits.htm