SUPERCHARGED SCIENCE

Unit 11: Magnetism

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Appropriate for Grades:
Lesson 1 (K-12), Lesson 2 (K-12)
Duration: 10-25 hours, depending on how many activities you do!

Why does a magnet stick to your fridge and not your soda can, even though *both* are magnetic? (No kidding!) And when you run magnets down a metal ramp, they defy gravity and slow to a stop. And how come the grapes from your lunchbox twist around to align with magnets, even though there's no iron inside? There's got to be a reason behind this madness… and that's what we're about to uncover.

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Materials for Experiments

How many of these items do you already have? We've tried to keep it simple for you by making the majority of the items things most people have within reach (both physically and budget-wise), and even have broken down the materials by experiment category so you can decide if those are ones you want to do.

NOTE: This material list is for the entire Experiment section online.

Basic Magnetism

Compass (at least one, but more is better)

Needle or thin nail

Cork or foam piece

Cup (non-metal)

Shallow baking dish (non-metal)

Caps from water bottles or milk jugs

2 strong magnets, both the same (RS #64-1895)

Assortment of magnets, one larger than the rest

Iron filings (you can take a metal file to a nail)

Disposable plate

Paper and pencil

Magnet wire (RS #278-1345)

8 donut-shaped magnets (RS #64-1888)

Packing peanuts (about 10)

Film canisters (2)

Long nails (2)

Sand paper (small 2" x 2" piece, fine grit)

D-cell battery

Bare wire OR aluminum foil

2 large paper clips

1 rubber band

String (3')

Tape, scissors

Optional: Clay (small piece)

Ultra-Cool Magnet Projects

In addition to the items for Basic Magnetism, you'll need these items below from Unit 10: Electricity:

4 AA battery packs (RS #270-408)

8 AA batteries (preferably NOT alkaline but rather the cheap 'heavy duty' dollar-store type)

LEDs (Radio Shack part #276-026, 276-012, 276-016, 276-311)

Buzzer (Radio Shack #273-053) or siren (#273-079)

3VDC motor (RS #273-223)

10 alligator clip leads (RS #278-1157)

AND YOU'LL ALSO NEED:

Small paper clips

Empty soup can or 2 large paper clips

6 large paper clips

4 brass fasteners

12VDC motor (RS #276-256)

Wooden ruler with groove down the center

8 strong rubber bands

9 nickel-plated ball bearings (NSBA)

Four ½" gold plated cubes (B888)

Screw (at least 1½" long)

5 disc magnets (DC2 from KJ Magnetics)

Aluminum sheet (like a cookie sheet)

Reed switch (RS #275-232)

Two large grapes

Straw

String (3')

Sticky tape (Scotch Magic tape works well)

Ferrofluid

Old laser printer cartridge (get these for free from a place that recycles them, like an office supply store)

Oil – vegetable or baby oil (only a few teaspoons)

Popsicle stick and disposable cup

Grades 9-12:

Buzzer/Shocker

DPDT Relay (RS #275-206)

Curie Engine:

Two tiny bead magnets (R211 and/or R311 from KJ Magnetics)

One ceramic magnet

Thin wire (28-32g)

Votive candle and lighter (keep out of reach)

Rail Accelerator:

9V battery clip (RS #270-325) & 9V battery

Aluminum foil (3' length)

Posterboard

1 wire coat-hanger (not insulated)

Two disc magnets (D21 from KJ Magnetics)

Two gold-plated disc magnets (D41G from KJ Magnetics)

Vice grips or cutters (to cut a wire coat hanger)

Listening to Magnetism

Bolt (2 ½" long and ¼" diameter) and 2 washers and a nut that fits the bolt

Mini Audio Amplifier from the Laser Communicator in Unit 9.

Strong magnet (borrow one of the ½" gold plated cubes from above list)

Cookie sheet (made from steel, not aluminum)

Speakers

You'll be making three different kinds of speakers here. If you haven't made these yet from Unit 6, NOW is the time to make them. Here's what you need:

Foam plate (paper and plastic don't work as well)
Sheet of copy paper
3 business cards
Magnet wire (RS #278-1345)

2 neodymium magnets (DA4)
1" donut magnet (RS #64-1388)
Index cards or stiff paper
Plastic disposable cup (not paper)
Tape
Hot glue gun
Scissors
1 audio plug (RS #42-2420) or other cable that fits into your boombox (iPODs and expensive stereos are not recommended for this project, as they will be damaged by the low resistance of the speakers)

Key Vocabulary

If an **atom** has more electrons spinning in one direction than in the other, that atom has a magnetic field. Atoms are made of a core group of neutrons and protons, with an electron cloud circling the nucleus.

The **Earth** has a huge magnetic field. The Earth has a weak magnetic force. The magnetic field probably comes from the moving electrons in the currents of the Earth's molten core. The Earth has a north and a south magnetic pole which is different from the geographic north and south pole.

Electricity is a flow of electrons. A flow of electrons creates a magnetic field. Magnetic fields can cause a flow of electrons. Magnetic fields can cause electricity.

Electrons can have a "left" or "right" spin in addition to 'going around' the nucleus. Electrons technically don't orbit the core of an atom. They pop in and pop out of existence. Electrons do tend to stay at a certain distance from a nucleus. This area that the electron tends to stay in is called a shell. The electrons move so fast around the shell that the shell forms a balloon like ball around the nucleus.

A **field** is an area around a electrical, magnetic or gravitational source that will create a force on another electrical, magnetic or gravitational source that comes within the reach of the field. In fields, the closer something gets to the source of the field, the stronger the force of the field gets. This is called the inverse square law.

Magnetic fields are created by electrons moving in the same direction. A magnetic field must come from a north pole of a magnet and go to a south pole of a magnet (or atoms that have turned to the magnetic field.) Iron and a few other types of atoms will turn to align themselves with the magnetic field. Compasses turn with the force of the 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**.

Magnetism is caused by moving electrons. Electricity is moving electrons. Electricity causes magnetism. Moving magnetic fields can cause electrons to move. Electricity can be caused by a moving magnetic fields.

All magnets have two **poles**. Magnets are called dipolar which means they have two poles. The two poles of a magnet are called north and south poles. The magnetic field comes from a north pole and goes to a south pole. Opposite poles will attract one another. Like poles will repel one another.

Unit Description

Did you know that if you cut a magnet in half to try to separate the north from the south pole, you'll wind up with two magnets, each with their own north and south poles? Turns out that the poles are impossible to separate!

Why does a magnet stick to your fridge and not your soda can, even though both are magnetic? (No kidding!) And when you run magnets down a metal ramp, they defy gravity and slow to a stop. And how come the grapes from your lunchbox twist around to align with magnets, even though there's no iron inside? There's got to be a reason behind this madness... would you like to find out what it is with me?

Now that you've spent a few lessons learning about the strange world of the atom (Unit 3 & Unit 8), it's time to discover which part of the atom is responsible for magnets and magnetic fields.

Objectives

Lesson 1: Magnets

What IS magnetism, anyway? You can feel how two north sides of a magnet push against each other, but what IS that invisible force, and why is it there? And how come magnets stick to the fridge and not a soda can? We'll about to dive seep into the mysterious world of magnetism. Although scientists are still trying to puzzle out some of its secrets, I'm going to get you up to speed on what they do know today. Are you ready?

You can get started by watching this video, and afterward either read more about it or start your experiments!

Highlights:

- 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.
- There's still a lot about fields that is unknown. Fields are an exciting area of physics where a lot is still left to be discovered.
- A field is an area around a electrical, magnetic or gravitational source that will create a force on another electrical, magnetic or gravitational source that comes within the reach of the field.
- In fields, the closer something gets to the source of the field, the stronger the force of the field gets. This is called the inverse square law.
- A magnetic field must come from a north pole of a magnet and go to a south pole of a magnet (or atoms that have turned to the magnetic field.)

- All magnets have two poles. Magnets are called dipolar which means they have two poles.
- The two poles of a magnet are called north and south poles.
- The magnetic field comes from a north pole and goes to a south pole.
- Opposite poles will attract one another. Like poles will repel one another.
- Iron and a few other types of atoms will turn to align themselves with the magnetic field.
- The Earth has a huge magnetic field.
- The Earth has a weak magnetic force.
- The magnetic field probably comes from the moving electrons in the currents of the Earth's molten core.
- The Earth has a north and a south magnetic pole which is different from the geographic north and south pole.
- Compasses turn with the force of the magnetic field.
- Over time iron atoms will align themselves with the force of the magnetic field.

Objectives

Lesson 2: Electromagnetism

This is one of the most important scientific discoveries of all time: moving magnets create electricity. Before this, people thought of electricity and magnetism as two separate things. When scientists realized that not only were they linked together, but that one causes the other, then the physics really started to fly!

In this lesson, we're going to take a closer look at how magnets create electricity by building electromagnets, galvanometers, motors, relays, telegraphs, and speakers. Are you ready?

You can get started by watching this video, and afterward either read more about it or start your experiments!

Highlights:

- Magnetism is caused by moving electrons.
- Electricity is moving electrons.
- Electricity causes magnetism.
- Moving magnetic fields can cause electrons to move.
- Electricity can be caused by a moving magnetic fields.
- Electricity is a flow of electrons.
- A flow of electrons creates a magnetic field.
- Magnetic fields can cause a flow of electrons.
- Magnetic fields can cause electricity.

Textbook Reading

Here's a riddle:

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?

Well, since you know the topic of this lesson this isn't the hardest riddle to solve. I'm a magnet right? Sure. But 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! So what is a magnet? What is going on with all those bizarre little shapes that are sticking to my fridge!?

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 the next lesson.

Electron Spin

"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.

Atomic Line Up

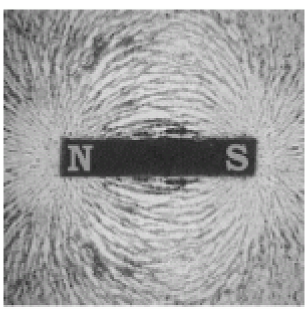
"Aha, so everything that's made of iron is magnetic! Got it."

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.

What's a magnetic field?



Well, I can't tell you. To be honest, nobody can. Magnetic fields, gravitational fields, electric fields are very mysterious and at this point there are still lots of questions about each one.

A field is an area around an electrical, magnetic or gravitational source that will create a force on another electrical, magnetic or gravitational source that comes within the reach of the field. (Now you can see why there's still so much mystery about them!)

A gravitational field, for example, comes from a body of some sort. The larger the body the greater the force. A planet, for example, is a large body with a large gravitational force. If another body gets within the gravitational field of the planet, it will be affected by the force.

What creates the force? What's pulling or pushing?

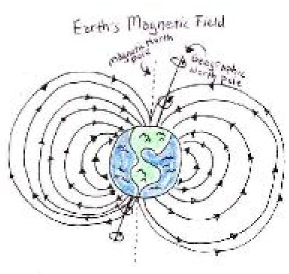
Nobody knows! We just know that it happens.

Another thing about forces is that the farther something gets away from the source, the less and less the force works on that object. A fancy term for this is the inverse square law. Something quite far from the Earth will feel no tug from the Earth's gravitational pull. If it gets closer it will feel a slight tug. Closer still, a stronger tug will be felt. The closer something gets to the source of a field (gravitational, magnetic or electric) the stronger the pull of the field force is. If you're standing on top of the Sears Tower in Chicago you are actually going to weigh less then if you're standing in the street.

Weight depends on the pull of gravity. The farther you are from the Earth, the less gravity pulls on you and the less you will weigh!

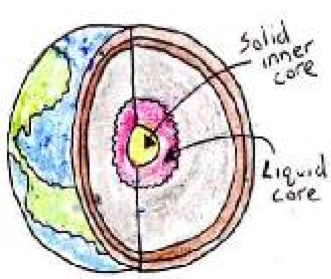
There's an instant diet plan for you!

A BIG Magnet



Right under your feet, there's a magnet. Go ahead take a look. Lift up your feet and see what's under there. Do you see it? It's huge! In fact, it's the largest magnet on the Earth. As a matter of fact, it is the Earth! That's right, the Earth is one huge, gigantic, monolithic magnet!

The Earth's a Magnet?



"But, we've learned that magnets need electrons flowing and the right metals and stuff like that. Is the Earth one big hunk of iron?"

No, but that's a good question. Where does the magnetic field come from? At this point, folks are still trying to figure that out. The most widely accepted theory is that the magnetic field comes from the Earth's core. The core of the Earth is solid but around that core is a liquid. The liquid is basically molten iron, nickel and a few other elements. It is the flowing of the electrons in this liquid metal that probably causes the Earth's magnetic field.

So, yes the Earth is a magnet, but not a very strong one. You probably couldn't even stick it to a sun size refrigerator. The Earth has a magnetic pull 100 times weaker then the magnets on your fridge. The Earth, by the way, is not the only giant magnet in the solar system. The Sun, Jupiter, Saturn, Uranus, Mercury and Neptune are also magnets.

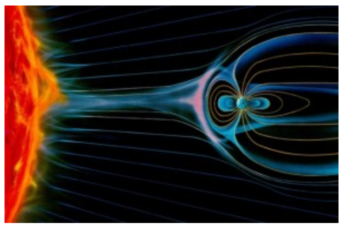
The Poles

"Oh, yeah. Now I remember. That's the deal with the North and South poles right?"

Well, yes and no. To confuse things a bit, there are two sets of North and South poles. There's the geographic North and South poles and the magnetic north and south poles. (To be completely honest, there are EIGHT magnetic poles on the Earth, but we'll just focus on the two strongest one for now to cut down on the confusion.)

The geographic poles are located at the axis of the Earth. The axis is where the Earth turns day after day. Like the top and bottom of a toy top. The magnetic poles are close to the geographic poles but they are off by quite a bit. (The south pole isn't even in Antarctica – it's in the ocean.) In fact, the north and south magnetic poles of the Earth move from year to year and have completely flipped a couple of times!

Magnetic Field

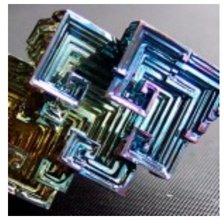


The Earth may be a weak magnet, but it has a gigantic magnetic field. The Earth's magnetic field gets warped by the Sun's solar winds. So on the side towards the Sun the field can reach over 43,500 miles or 70,000 km into space.

On the side away from the Sun, the field can stretch out much farther. This field forms a bit of a barrier against the cosmic rays from the Sun and is called the magnetosphere.

Sun flares often hit this magnetosphere and create auroras. Auroras are beautiful light shows in the sky that normally take place in the very northern or southern hemispheres.

Diamagnetic



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 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

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 start to really line up. Paramagnetic materials are attracted to both ends of a magnet.

Ferromagnetic

There are 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.

Antiferromagnetic

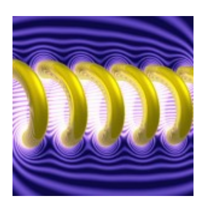
Some paramagnetic materials (like chromium and manganese) have atoms pair up and cancel each other out. The north pole of one atom will line up with the south pole of another.

Electromagnets

Now we've covered the fact that magnetic fields are caused by electrons moving in the same direction. Up to this point, we've been focusing on magnetism being caused by an unequal number of electrons spinning in the same direction in an atom.

If an atom has more electrons spinning in one direction than in the other direction, that atom will have a magnetic field. When bunches of these atoms get together, we have a permanent magnet. Now we're going to talk about what happens if we force electrons to move.

Moving magnets create electricity?



This is one of the most important scientific discoveries of all time.

One story about this discovery, goes like this:

A science teacher doing a demonstration for his students (can you see why I like this story) noticed that as he moved a magnet, he caused one of his instruments to register the flow of electricity. He experimented a bit further with this and noticed that a moving magnetic field can actually create electrical current. Thus tying the magnetism and the electricity together.

Before that, they were seen as two completely different phenomena! Now we know, that you can't have an electric field without a magnetic field. You also cannot have a moving magnetic field, without causing electricity in objects that electrons can move in (like wires). Moving electrons create a magnetic field and moving magnetic fields can create electric currents.

"So, if I just made electricity, can I power a light bulb by moving a magnet around?"

Yes, if you moved that magnet back and forth fast enough you could power a light bulb. However, by fast enough, I mean like 1000 times a second or more! If you had a stronger magnet, or many more coils in your wire, then you could make a greater amount of electricity each time you moved the magnet through the wire.

Believe it or not, most of the electricity you use comes from moving magnets around coils of wire! Electrical power plants either spin HUGE coils of wire around very powerful magnets or they spin very powerful magnets around HUGE coils of wire. The electricity to power your computer, your lights, your air conditioning, your radio or whatever, comes from spinning magnets or wires!

"But, what about all those nuclear and coal power plants I hear about all the time?"

Good question. Do you know what that nuclear and coal stuff does? It gets really hot. When it gets really hot, it boils water. When it boils water, it makes steam and do you know what the steam does? It causes giant wheels to turn. Guess what's on those giant wheels. That's right, a huge coil of wire or very powerful magnets!

Coal and nuclear energy basically do little more than boil water. With the exception of solar energy almost all electrical production comes from something huge spinning really fast!

In this unit, we're going to make several really fun gadgets that rely on this 'electricity makes magnetism' and 'magnetism makes electricity' thing. You'll be able to baffle most grown-ups with these creations!

How magnets make sound

We've come a long way with this magnetism thing and hopefully you're feeling pretty good about how magnetism works and what it does. Now we're going to use what we've learned to make simple versions of two gadgets that you use every day.

Let's start with the slightly simpler gadget. Now to understand what's happening here, we need to recap: Remember, that electricity is moving electrons and what do moving electrons create? A magnetic field.

Also, remember that a magnetic field, when moved near a metal that can conduct electricity, will create an electric current in that metal.

Magnetism can create electricity and electricity can create magnetism. Now, let's go way back in time and try to remember the work we did with sound in Unit 6. Sound is vibrations. If something vibrates between a frequency of 20-20,000 Hz our ears can detect it as sound.

To make a speaker, we need to somehow make something vibrate. "Hmmm, I wonder if this magnetism/electricity could somehow be useful here."

So what's going on with a speaker? What makes it work? Okay, here's the deal. The radio provides the electricity that gets pumped through the wires. The radio very quickly pumps electricity in one direction and then switches to pump it in the other direction. This movement of electrons back and forth creates a magnetic field in the coil of wire.

Since the electricity keeps reversing, the magnetic field keeps reversing. Basically, the poles on the electromagnet formed by the coil go from north to south and back again. Since the poles keep reversing, the permanent magnet you have taped to the cup keeps getting attracted, then repelled, attracted, then repelled. This causes vibrations.

The speaker cone (or cup, as in the speaker we're going to make) that's strapped to the coil and magnet acts as a sound cone. The magnet causes the sound cone to vibrate and since it's relatively large, it causes air to vibrate. This is the sound that you hear.

Almost all speakers work just like the one you are going to create in this unit. They just use fancier materials so that the sound is louder and clearer.

Activities, Experiments, Projects

Lesson 1: Magnets

Note: This section is an abbreviated overview of the experiments online.

Experiment: Simple Magnet Activities

Let's play around with the idea of lining up all the mini-magnets inside an object to magnetize it. You'll need a steel nail (steel is a combination of iron and carbon), a magnet (the stronger the better), and a few paper clips. Here's what you do:

1. Take a nail in one hand and the magnet in the other.

2. Stroke the magnet along the nail. Make sure to always stroke in the same direction. From the head to the tip for example. Do that at least twenty times.

3. Now see if your nail can pick up any paper clips. Feel free to strengthen your magnet nail by continuing to stroke the nail with the permanent magnet.

You actually twisted and turned atoms! As you moved the permanent magnet over the nail the iron atoms in the nail actually turned, to align themselves with the magnetic field of the magnet. Once enough iron atoms turned the nail itself became a magnet!

Now let's destroy the magnetized nail... and turn it back into a regular old nail. Here's what you do:

1. Drop it on a hard surface. A table, floor or sidewalk would work well.

2. Drop it again.

3. Drop it again.

4. Drop it....you get the picture. Drop it four or five times.

5. Now see if it picks up any paper clips. Is the nail still a magnet?

Here you took atoms that were all nicely lined up and messed them up so they pointed in different directions. Since they weren't lined up as nicely anymore they had much less or perhaps no magnetic force. If you remember the magnets in a box that we were talking about before. This is like you took that box that had all the magnets lined up and dropped it. CRASH! They get all jumbled up and next thing you know the box no longer has nearly as strong of a magnetic force.

Magnets Are Picky Where They Are Sticky

"So, how come I can get a magnet to stick to a refrigerator but not my brother's head?" Ah, I'm glad to see that you're experimenting! (You might not want to use your siblings as test subjects though...just a thought.) In a way, you could say that magnets only stick to other magnets. I know you refrigerator is not a magnet but bear with me for a second. Your fridge is made of a metal that has iron in it.

Remember that each iron atom is kind of like a little magnet. So your fridge is made of bunches of little magnets. The reason you can't stick paper clips to your fridge is that all those little "atom magnets" are pointing in different directions and canceling out their magnetic fields. But what happens when a magnetic field gets close to those little "atom magnets"? They turn. The atoms turn so that their poles are opposite of the poles of the magnet. (We'll talk more about poles in a later lesson.)

Since they have turned, they now act like a magnet and the fridge magnet can now be attracted to the atoms in the fridge. Once you remove the fridge magnet, the atoms in that part of the fridge go back to being mixed up. Here's what you do:

1. Attach a paper clip to your magnet.

2. Can you dangle another paper clip from the end of your first one?

3. How many can you dangle from each other. Two, three, four, more?

4. What happens if you remove the permanent magnet from the top of the chain?

The paper clips became temporary magnets didn't they? The permanent magnet turned the iron atoms in the paperclips so that they aligned with the field of the permanent magnet. Since those atoms are all facing in a similar direction, they can now create a magnetic field of their own. So the paper clip becomes a magnet as long as a magnet is near it. Once the permanent magnet gets too far away, the atoms go back to mish-mosh and no longer have much of a magnetic field.

Activities, Experiments, Projects

Lesson 2: Electromagnetism

Note: This section is an abbreviated overview of the experiments online.

Experiment: Motors and Generators

Have you noticed that stuff sticks to your motor? If you drag your motor through a pile of paperclips, a few will get stuck to the side. What's going on?

Inside your motor are permanent magnets and an electromagnet. Normally, you'd hook up a battery to the two tabs (terminals) at the back of the motor, and your shaft would spin.

However, if you spin the motor shaft with your fingers, you'll generate electricity at the terminals. But how is that possible? That's what this experiment is all about.

If you move a magnet along the length of a wire, it will create a very faint bit of electricity inside the wire. If you moved that magnet back and forth fast enough you could power a light bulb. However, by fast enough, I mean like 1000 times a second or more!

If you had a stronger magnet, or many more coils in your wire, then you could make a greater amount of electricity each time you moved the magnet past the wire.

A motor has a coil of wire wrapped around a central axis, so instead of rubbing back and forth (which is tough to going fast enough, because you have to stop, reverse direction, and start moving again every so often), it rotates past a set of magnets continuously.

When you add a battery pack to the motor terminals at the back, you energize the coil inside the motor, and it begins to rotate to attempt to line up its north and south poles. But the magnets are lined up in a way that it will continually 'miss' and overshoot, which keeps the shaft spinning over and over, faster and faster.

You can transform a motor into a generator by doing the opposite:

1. You can turn your motor into a generator by simply giving the shaft a quick spin with your

fingers. Remember that attached to this shaft is a coil of wire. When you spin the shaft, you're also moving a coil of wire past the permanent magnets inside to motor, which will create electricity in your coil and out the terminals.

2. Attach a low-voltage bipolar LED (RS #276-012) directly to the motor terminals. Bend the end of each 'leg' of the LED into little hooks and hook one to each motor terminal.
3. Spin the shaft to see the LED light up. Depending on the size of the magnets inside your motor, you may need to spin the shaft super fast to see the LED light up. The larger the motor, the easier this activity is. Try using a 9-18VDC motor (RS #276-256) from Radio Shack.

Experiment: Galvanometers

Galvanometers are coils of wire connected to a battery. When current flows through the wire, it creates a magnetic field. Since the wire is bundled up, it multiplies this electromagnetic effect to create a simple electromagnet that you can detect with your compass.

1. Remove the insulation from about an inch of each end of the wire. (Use sandpaper if you're using magnet wire.)

2. Wrap the wire at least 30-50 times around your fingers, making sure your coil is large enough to slide the compass through.

3. Connect one end of the wire to the battery case wire using an alligator clip wire.

4. While looking at the compass, repeatedly tap the other end of the wire to the battery. You should see the compass react to the tapping.

5. Switch the wires from one terminal of the battery to the other. Now tap again. Do you see a difference in the way the compass moves?

You just made a simple galvanometer. "Oh boy, that's great! Hey Bob, take a look! I just made a....a what?!?" I thought you might ask that question. A galvanometer is a device that is used to find and measure electric current. "But, it made a compass needle move...isn't that a magnetic field, not electricity?" Ah, yes, but hold on a minute. What is electric current...moving electrons. What do moving electrons create...a magnetic field! By the galvanometer detecting a change in the magnetic field, it is actually measuring electrical current! So, now that you've made one let's use it!

More experiments with your galvanometer:

You will need:

- Your handy galvanometer
- The strongest magnet you own
- Another 2 feet or more of wire
- Toilet paper or paper towel tube

1. Take your new piece of wire and remove about an inch of insulation from both ends of the wire.

2. Wrap this wire tightly and carefully around the end of the paper towel tube. Do as many wraps as you can while still leaving about 4 inches of wire on both sides of the coil. You may want to put a piece of tape on the coil to keep it from unwinding. Pull the coil from the paper towel tube, keeping the coil tightly wrapped.

3. Hook up your new coil with your galvanometer. One wire of the coil should be connected to one wire of the galvanometer and the other wire should be connected to the other end of the galvanometer.

4. Now move your magnet in and out of the coil. Can you see the compass move? Does a stronger or weaker magnet make the compass move more? Does it matter how fast you move the magnet in and out of the coil?

Taa Daa!!! Ladies and gentlemen you just made electricity!!!!! You also just recreated one of the most important scientific discoveries of all time. Moving electrons create a magnetic field and moving magnetic fields can create electric currents.

Experiment: Electromagnet

You can also wrap your wire around an iron core (like a nail), which will intensify the effect and magnetize the nail enough for you to pick up paperclips when it's hooked up. See how many you can lift!

Find these materials:

- Batteries in a battery holder with alligator clip wires
- A nail that can be picked up by a magnet
- At least 3 feet of insulated wire (magnet wire works

best but others will work okay)

- Paper Clips
- Masking Tape
- Compass

1. Take your wire and remove about an inch of insulation from both ends. (Use sandpaper if you're using magnet wire.)

2. Wrap your wire many, many times around the nail. The more times you wrap the wire, the stronger the electromagnet will be. Be sure to always wrap in the same direction. If you start wrapping clockwise, for example, be sure to keep wrapping clockwise.

3. Now connect one end of your wire to one terminal of the battery using an alligator clip (just like we did in the circuits from Unit 10).

4. Lastly, connect the other end of the wire to the other terminal of the battery using a second alligator clip lead to connect the electromagnet wire to the battery wire. This is where the wire may begin to heat up, so be careful.

5. Move your compass around your electromagnet. Does it affect the compass?

6. See if your electromagnet can pick up paper clips.

7. Switch the wires from one terminal of the battery to the other. Electricity is now moving in the opposite direction from the direction it was moving in before. Try the compass again. Do you see a change in which end of the nail the north side of the compass points to?

What happened there? By hooking that coil of wire up to the battery, you created an electromagnet. Remember, that moving electrons causes a magnetic field. Well, by connecting the two ends of your wire up to the battery, you caused the electrons in the wire to move through the wire in one direction. Since many electrons are moving in one direction, you get a magnetic field! The nail helps to focus the field and strengthen it. In fact, if you could see the atoms inside the nail, you would be able to see them turn to align themselves with the magnetic field created by the electrons moving through the wire. You might want to test the nail by itself now that you’ve done the experiment. You may have caused it to become a permanent magnet!

Exercises

Lesson 1: Magnets

1. What happens when you break a magnet in half? Can you separate the North and South poles?

2. What causes magnetism?

3. Why does your refrigerator magnet stick to the fridge door?

4. Is aluminum magnetic, electrically conductive, or both?

5. What elements would you guess to be in a magnet? Can you name three?

6. What causes (or creates) magnetic field?

7. Name the biggest magnet you can think of.

8. Where is the magnetic south pole?

9. What happens when you heat up a magnet?

10. Why is the grape repelled by the magnet?

11. Why does the magnet go slowly down the ramp?

Exercises

Lesson 2: Electromagnets

Don't be misled by the number of questions here - if you've answered these accurately, you've mastered the lesson.

1. How does a moving magnet make electricity?

2. What's an electromagnet?

3. How does the DC motor you built work?

4. What is a reed switch?

5. How does a magnet make sound?

Answers to Magnets Exercises

1. You get two smaller magnets, each with their own north and south pole. You cannot separate the north and south pole of a magnet.

2. Electrons. More accurately, a majority of electrons moving in a similar direction creates a magnetic field.

3. 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).

4. Aluminum conducts electricity, but is not magnetic as detectable by the human eye (called ferromagnetic). Aluminum is technically paramagnetic (very weakly attracted to both poles of a magnet).

5. Iron, nickel, and cobalt are ferromagnetic (attracted to both poles of the magnet).

6. A magnetic field is something I can't tell you about – it just is (like gravity). Best thing I can do is tell you that a field is an area around an electrical, magnetic or gravitational source that will create a force on another electrical, magnetic or gravitational source that comes within the reach of the field.

7. The earth. On a universe-scale, magnetars (magnetized neutron stars) are the biggest known magnets out there.

8. Off the coast of Antarctica in the ocean.

9. When you heat a magnet past the 'Curie Temperature', the magnet loses its magnetism. Once cooled back down, it will regain magnetism again.

10. The grape contains sugar water, which is diamagnetic (repelled by both poles).

11. The eddy currents in the metal plate created by the moving (sliding) magnet slow down the magnet and counteracts gravity.

Answers to Electromagnets Exercises

1. If you moved that magnet back and forth along a wire-wrapped nail fast enough you could power a light bulb. (However, by fast enough, I mean like 1000 times a second or more!)
2. A magnet that you can turn on and off using electricity. An example is a nail wrapped in a coil of wire, powered by a battery pack.
3. The coil is magnetized (becomes an electromagnet) and is momentarily attracted to the permanent magnet and starts to align itself with it, but as it does, it breaks the connection and the coil becomes just a piece of unmagnetized wire, which continues to rotate from the previous pull (when it was magnetic). As it does, the coil energizes again, now repelling itself and pushing itself away as it tries to align itself with the magnet again, and as it does, the electricity goes off again, allowing the coil to rotate freely (and not get stuck in one position). And on it goes.
4. It's a switch that connects (turns on) when a magnet is close by. The two small steel plates hit each other and allow electricity to flow.
5. Magnetism can create electricity and electricity can create magnetism. Sound is vibrations. To make a speaker, we need to somehow make something vibrate. The radio provides the electricity that gets pumped through the wires. The radio very quickly pumps electricity in one direction and then switches to pump it in the other direction. This movement of electrons back and forth creates a magnetic field in the coil of wire. Since the electricity keeps reversing, the magnetic field keeps reversing. Basically, the poles on the electromagnet formed by the coil go from north to south and back again. Since the poles keep reversing, the permanent magnet you have taped to the cup keeps getting attracted, then repelled, attracted, then repelled. This causes vibrations. The speaker cone (or cup, as in the speaker we're going to make) that's strapped to the coil and magnet acts as a sound cone. The magnet causes the sound cone to vibrate and since it's relatively large, it causes air to vibrate. This is the sound that you hear.

