STEM Lesson Plan:

NATIONAL MAGLAB
Research Experiences FOR TEACHERS

Electricity and Magnetism Career Explorations for Physical Science Students: Hands on activities and research opportunities from the National Magnet Lab (Middle School)

Purpose:

Content Objective: I will be able to (SWBAT) identity connections between Electricity and Magnetism unit skills, such as building circuits and utilizing magnetic fields, with potential future careers by practicing unit 5 skills and investigating unit 5 related careers

Language Objective: I will read the profiles of professionals in familiar and unfamiliar careers and write reflections on how their work relates to my work in physical science

Next Generation Sunshine State Standards:

- **MS-ETS1-4** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved
- **MS-PS2-3** Ask questions about data to determine the factors that affect the strength of electrical and magnetic forces
- **MS-PS2-5** Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between object exerting forces on each other even though the objects are not in contact
- **HS-PS2-5** Plan and conduct an investigation to provide evidence that an electrical current can produce a magnetic field and that a changing magnetic field can produce an electrical current
- **NGSS Appendix H** - Understandings about Nature of Science
    - Scientific knowledge is a result of human endeavor, imagination and creativity
    - Individuals and teams from many nations and cultures have contributed to science and to advances in engineering

Virginia Standards of Learning:

- PS.1 The student will demonstrate an understanding of scientific and engineering practices by
    - f) obtaining, evaluating, and communicating information read scientific texts, including those adapted for classroom use, to determine the central idea and/or obtain scientific and/or technical information
- PS.9 The student will investigate and understand that there are basic principles of electricity and magnetism. Key ideas include
    - b) materials have different conductive properties;

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- c) electric circuits transfer energy;
- d) magnetic fields cause the magnetic effects of certain materials;
- e) electric current and magnetic fields are related; and
- f) many technologies use electricity and magnetism

Time: 60 minutes

Enduring Understandings

Electricity is the result of charged particles; most electrical applications use moving elections to create a flow of electric current; there is a relationship between electricity and magnetism; many in-demand careers utilize electricity and magnetism concepts

Essential Questions

- How can I model and demonstrate electrical/magnetic fields?
- What career path could I follow if I have an understanding of and interest in Unit 5 Electricity and Magnetism concepts?
- What properties of materials are useful in electronic technology?

Vocabulary:

- Charge
- Magnetic field
- Electric circuit
- Electronic circuit
- Electromagnet
- Software
- Hardware
- Engineer
- Spectrometry
- MRI

Materials:

- Student interactive notebook
- Stations companion packet [appendix I]
- Station instructions [appendix II]
- Professional profiles [appendix [III]
- 2 D Batteries
- Copper wire (1 piece small gauge and 1 piece large gauge)
- Simple circuit supplies: battery holder, paper clips, alligator clips
- 3 neodymium magnets (note: I have not been able to make the homopolar motor work with ceramic magnets but it, I believe, is technically possible)

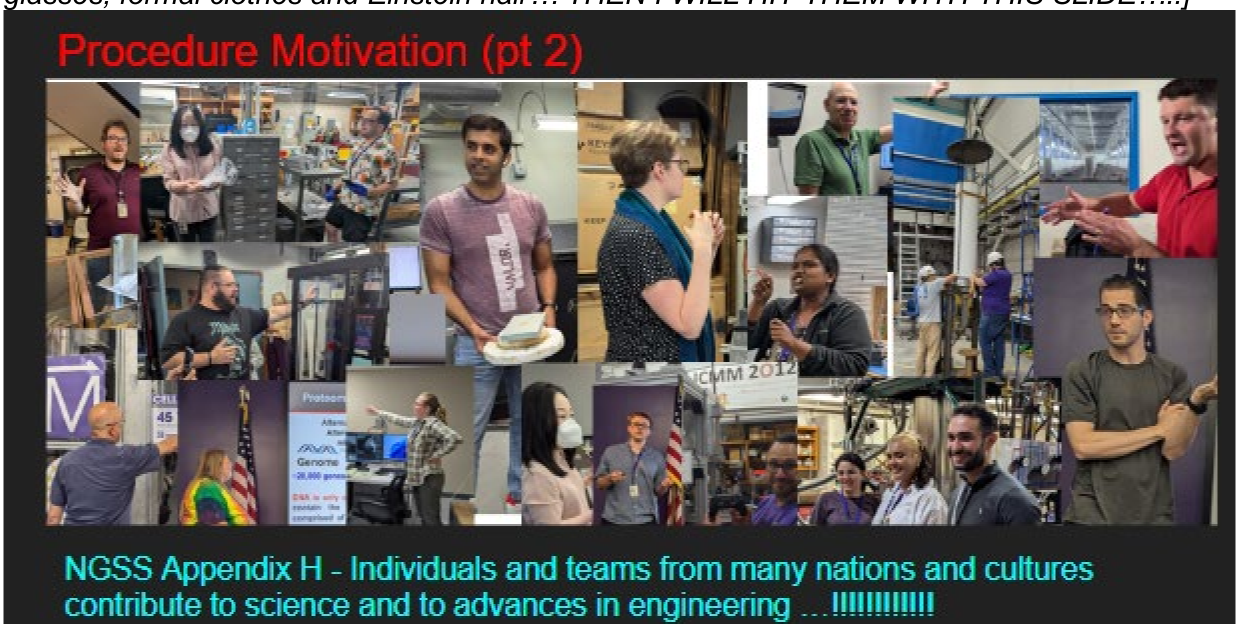
STEM Lesson Plan:

- Magnetic field demonstration supplies: cardboard box and string; bar magnets; iron filling sheets (or iron filings in plastic bag), small compasses

Procedure Motivation:

Students begin each class with a warm-up. The established classroom routine is to immediately retrieve their interactive notebook from the period box once they enter the classroom and begin the warm-up on the whiteboard. The warm-up for this lesson is: When you think of a scientist, what do you think of? Students will be encouraged to draw or write down their ideas.

[Leonberger note: I have tried this exercise with previous students and their drawings/descriptions frequently follow a stereotypical idea of a scientist: older white man with glasses, formal clothes and Einstein hair… THEN I WILL HIT THEM WITH THIS SLIDE….!]



Discuss as a class: Do the people in this image match what you wrote or drew? Why or why not?

[Leonberger note: All of these images were taken by me during the 2024 Research Experience for Teachers at the National High Magnetic Field Laboratory - the people in the images represent many different genders, races, nationalities, disabilities, and education levels. I went out of my way to include these differences but also people wearing "casual" clothing. If you want to use a different set of images I recommend the website "I Am A Scientist" https://www.iamascientist.info/stories]

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Presentation:
After the warm-up, students will check their guided notes from the previous class's lesson to make sure everyone is ready to move on to the stations. Then, the teacher will pass out the station companion sheets. The students will trim and paste the papers into their interactive science notebooks. The students will follow along with the teacher as they go through the directions. As this is happening, the teacher will be constantly checking for understanding and application of prior knowledge.

Practice
Students will be shown one of the stations as a demonstration. This will ensure that students understand the directions as they move from whole group instruction and into group-based application of concepts. The station is about the difference between generators and motors. The station is based on having a hand-crank device and a battery (or electric powered) fan. The hand crack is a generator and the battery/electric fan is run by a motor. [Leonberger note: personally, I use a hand crank emergency radio for the generator and a desk fan for the motor - but if you don't have access to these things I think a video of both would work just as well]

Application

Students will get into groups of 3 or 4 and move around the room visiting the different stations. Some stations are hands-on applications and some are reading responses. Instructions will be on the papers in their Observation Notebooks and also at the stations themselves.

Appendix I [Student Companion Packet] pages 5 – 7
Appendix II [Station Instructions] pages 8 – 15
Appendix III [Professional Profiles] pages 16 – 18

[Leonberger Note: My goal is to replace these professional profiles from imascientist.info with professional profiles that I make from interviews with professionals that I know personally/can contact personally. This page https://docs.google.com/document/d/14cM-XDNNJS8d1U5MP_3o0Z0tG4MsW-raotW0Pinl2IE/edit?usp=sharing will be updated when I have completed these profiles!! In the meantime, all thanks to the website https://www.iamascientist.info/ which is really a great resource in general!!!]

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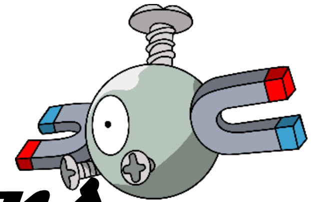
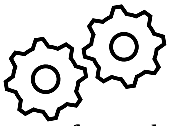
Name:____ Date:___________________ Pd:____________

Electricity & Magnetism Stations





Example Station: Motors VS Generators

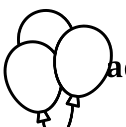
Motors transform electrical energy into mechanical energy. Generators transform mechanical energy into electrical energy. Watch the demonstration and answer the questions below:

Which object is the generator? _______________ How did you know? ____________________

____

Which object is the motor? _________________ How did you know? ____________________

____



Station #1: "Roll With It Can"

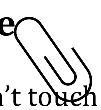
adapted from "Junk Drawer Physics" by Bobby Mercer

At this station you will find an inflated balloon, some fuzzy fabric, and some aluminum cans. First, use the fabric to build up a static charge on the balloon by rubbing the fabric on the balloon quickly. You can also use your hair to build up the charge. Either way, don't press on the balloon too hard or you'll pop it! Once you have rubbed it for a few minutes, place it near an aluminum can on its side. What happens?

Describe what happens: ____

Read "The Science Behind It" on the station instructions. Then, draw a model of what happened in his demonstration in the place to the right. Make sure to include minus signs ("-") for negative charges and plus signs ("+") for positive charges!!

Station #2: Paper Clip Challenge



First, get the first paperclip in the magnetic field of the hanging magnet. Don't touch the paperclip directly to the magnet, instead, the paperclip should be suspended upright without touching the magnet directly! Try and attach as many paperclips to the first paperclip as you can without any of them touching the hanging magnet. Can you beat Ms. Leonberger's record?

How many paperclips were you able to attach before they all fell? ______ What made the pull between the paperclips and the magnet stronger? ____

Station #3: Electromagnetic Induction

Use the infographic to learn about how "wireless" or electromagnetic induction charging works and answer the questions below.

1) **What vocabulary term, that describes the reach of a force without directly touching explains how wireless charging works? ______________________________**

2) **Explain, in your own words, how electromagnetic induction works.** __________________________

____

____

Station #4: Homopolar Motor

(image and more information available from https://www.wikihow.com/Make-a-Homopolar-Motor)

First, use the "original" heart-shaped wire to create a "homopolar motor" electromagnet. Place the battery (**flat, negative terminal down**) on the stack of magnets and balance the loop of the copper wire on the positive terminal. If the wire is placed properly (with the loop balanced on the positive terminal and the bottom wires of the heart on either side of the magnet stack) it should spin!

Once you have made the original design work, use the "experimental" wire and pliers to make your own design!

ELA Connection! You may have never heard the term "homopolar" before, but you might recognize the prefix "homo-" and the root word "pole". After reading the explanation on the station instruction, make a hypothesis about what you think the word "homopolar" means: ____

Station #5: Simple Circuits

Recall that electrical energy flows through a wire like water flows through a pipe. In order for this flow to happen, you must have a complete circuit. Use the materials at this station to create an electrical current that flows from the battery to the light bulb.

Materials: alligator wires, battery holder, battery, light bulb platform, light bulb, switch (optional)

Once you have made a successful circuit, draw it below:

Station #6: Iron Filings Magnetic Fields

In the yellow folder you will find a bar magnet and a Ziploc bag of iron filings. Do not open the bag! You will observe the behavior of the filings through the bag.

What happens when you move the bar magnet back and front over the iron filings? ______________________

____

What happens when you place the bag on top of the yellow folder and the bar magnet under it? **<u>Draw</u>** the pattern that is created, below:

What you have drawn has a name, what is it? ____

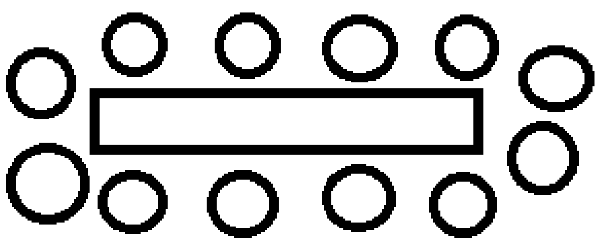
Station #7: Compass Magnetic Fields

In the cardboard tray you will find 12 compasses and a bar magnet. When you are done with the compasses, place them back in the corner section! DO NOT LOSE ANY COMPASSES.

What happens when you move the bar magnet back and front over the compasses? ______________________

____

What happens when you place the compasses around the bar magnet? **<u>Draw</u>** what happens, below:



Station #8: Career Explorations

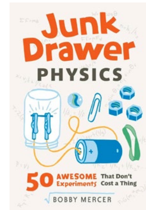
Many jobs and careers include the scientific principles that you have experienced today! Choose at least one of the "Professional Profiles" located at the station, read it, and then answer the questions below!

What profession did you read about? ____

Describe the professional's job or career using at least one of the vocabulary terms in the unit word bank:

Word Bank: magnet, electricity, conductor, insulator, circuit, field, current, electronics, design, motor, generator, electromagnet, engineer	

Station #1: “Roll With It Can”



Adapted from “Junk Drawer Physics” by Bobby Mercer

Use the fuzzy fabric OR your hair to build up a charge on the surface of the balloon (BE CAREFUL NOT TO POP THE BALLOON!). Then place the balloon near the aluminum can (the can should be on its side on a flat surface, like the desk). What happens?

The Science Behind It

All matter is composed of *positive charges* (*protons*), *neutral charges* (*neutrons*), and *negative charges* (*electrons*). Rubbing the balloon causes invisible electrons to be transferred from your sock (or hair) to the balloon. The balloon side you rubbed on your socks is now negative because it gained electrons. The sock is positive, but it is only used to give electrons to the balloon. In electricity, opposites attract and like charges repel. So electrons (negative charges) will attract protons (positive charges) and repel other electrons. Neutrons don't help us any in electricity.

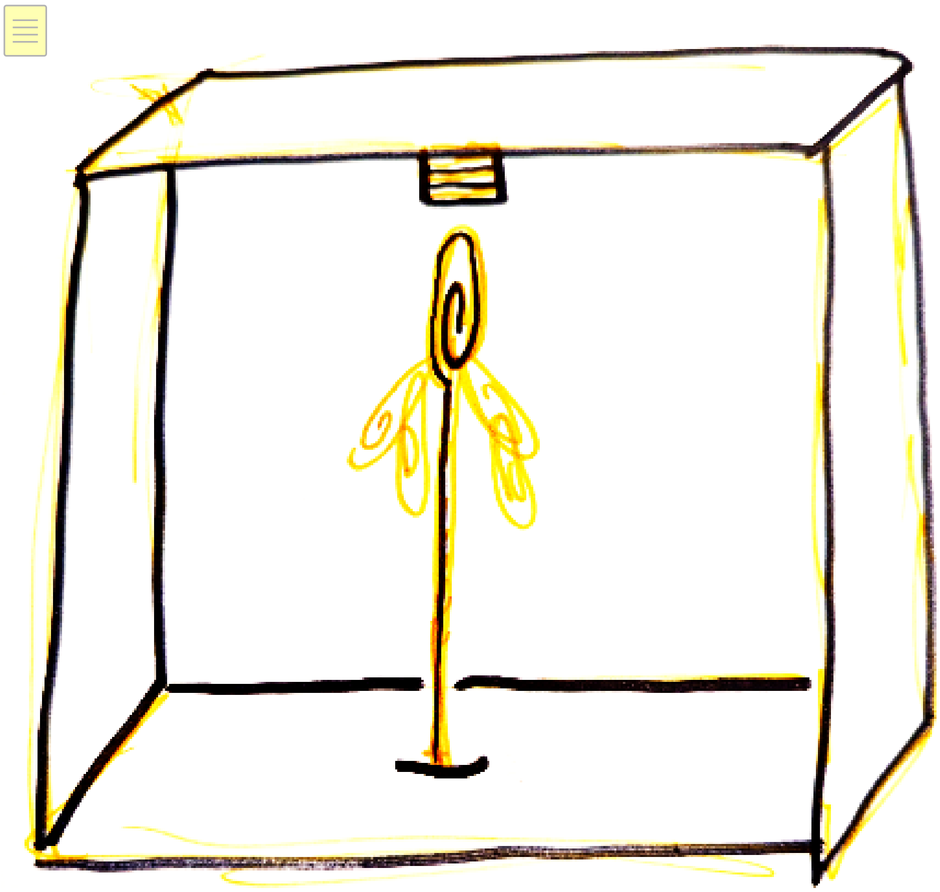
The negative charge will attract a neutral object, like the aluminum can, because the side of the empty can nearest the negative side of the balloon will become positive as negative electrons in the can run away from the balloon. The can is still neutral since the electrons haven't left it, they just moved to the other side. The side of the empty can nearest the balloon is positive and the farthest side is negative. The negative balloon attracts the positive side of the can.

Empty cans on a flat, smooth surface have only a small amount of friction and will roll toward the balloon. As the can rolls, some of the negative electrons continue to shift away from the balloon, so it keeps rolling. The side of the can near the balloon stays positive as long as the balloon is present. When you remove the balloon, the electrons in the can go back to where they started.

Static electricity works best on cold, dry days. If it is rainy or muggy, static electricity experiments don't work as well. High humidity means there is a lot of water vapor in the air. Water molecules are *polar* and have a positive and a negative side. If there is a lot of water vapor, the electrons will jump to the positive side of the water molecules and you won't be able to build up a very good static charge.

“The Science Behind It” p. 135 of “Junk Drawer Physics”

Station #2: Paper Clip Challenge



Lift the anchor paper clip (the one attached to the string) into the magnetic field of the magnets on the top of the tray (it should NOT DIRECTLY TOUCH the magnet, see how it should look above). Attach the additional paper clips to the anchor clip (as shown as yellow in the image above). Add paper clips until the anchor falls!

Station 3: Electromagnetic Induction

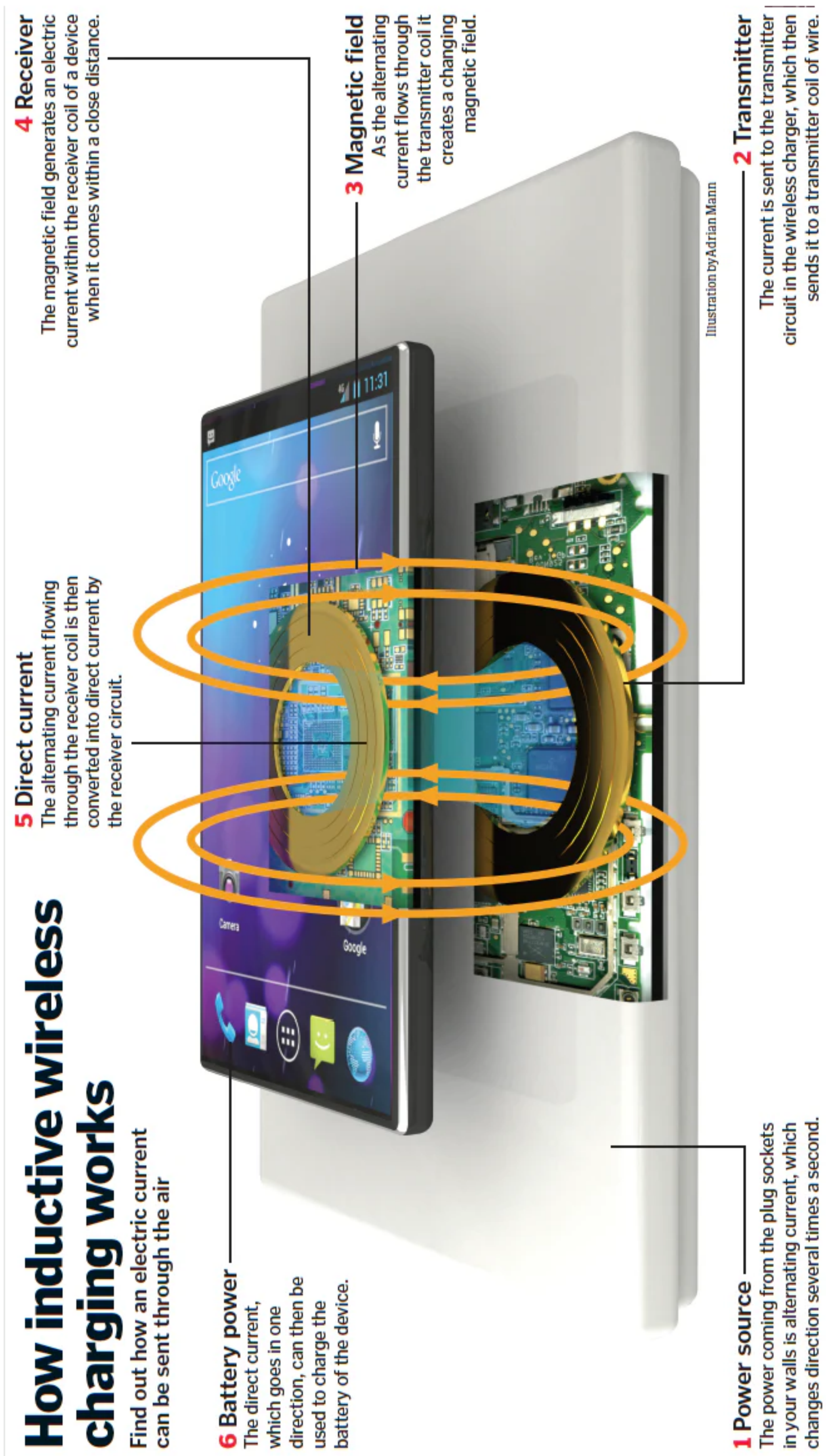
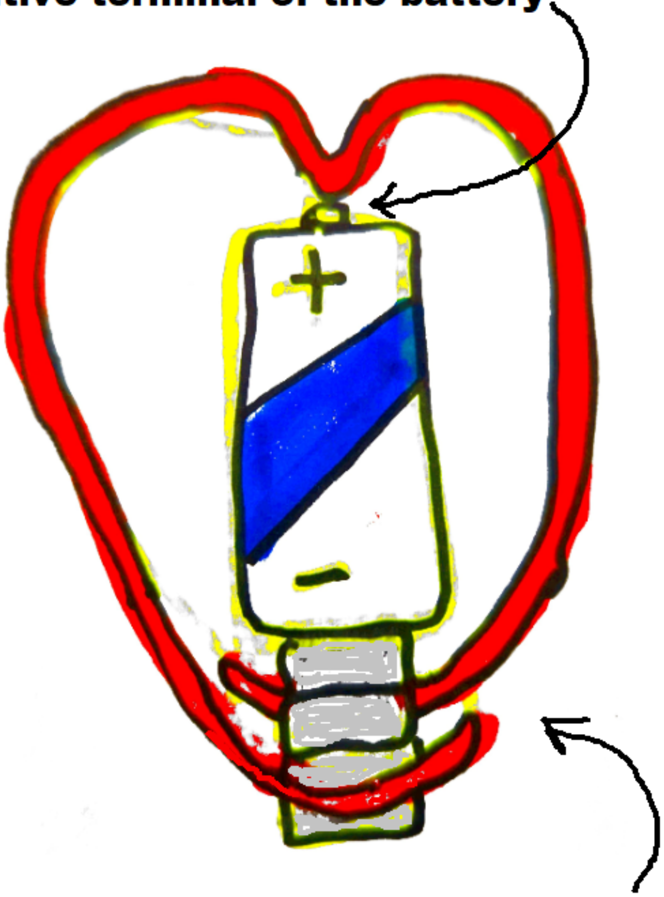


Image sourced from https://keutek.com/blogs/news/is-it-possible-to-charge-phones-wirelessly

Station #4: Homopolar Motor

The copper wire should balance just on the bump of the positive terminal of the battery



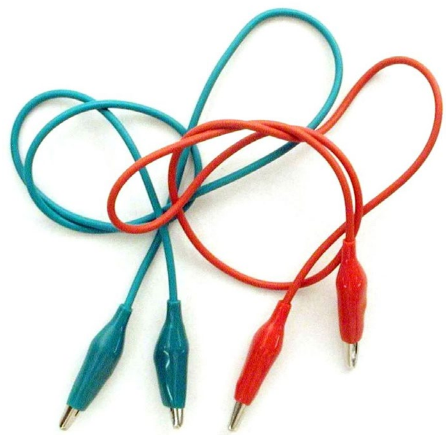
The ends of the copper wire should be curled around the magnets without touching the magnets directly

How does it work?

A motor is a device that turns electrical energy into mechanical energy. The homopolar motor turns chemical energy from the battery into electrical energy in the copper wire. The wire spins because of something called the Lorentz force, which states that if you push an electrical current through a wire in the presence of a magnetic field, the current will want to move in relation to the field. As long as the copper wire is in the magnet field (but not physically caught on the magnet), a “torque” force will rotate it around the battery (until the battery runs out of energy)!

Station #5: Simple Circuits

Use these materials to complete a circuit - you'll know the current is flowing once the light bulb turns on!

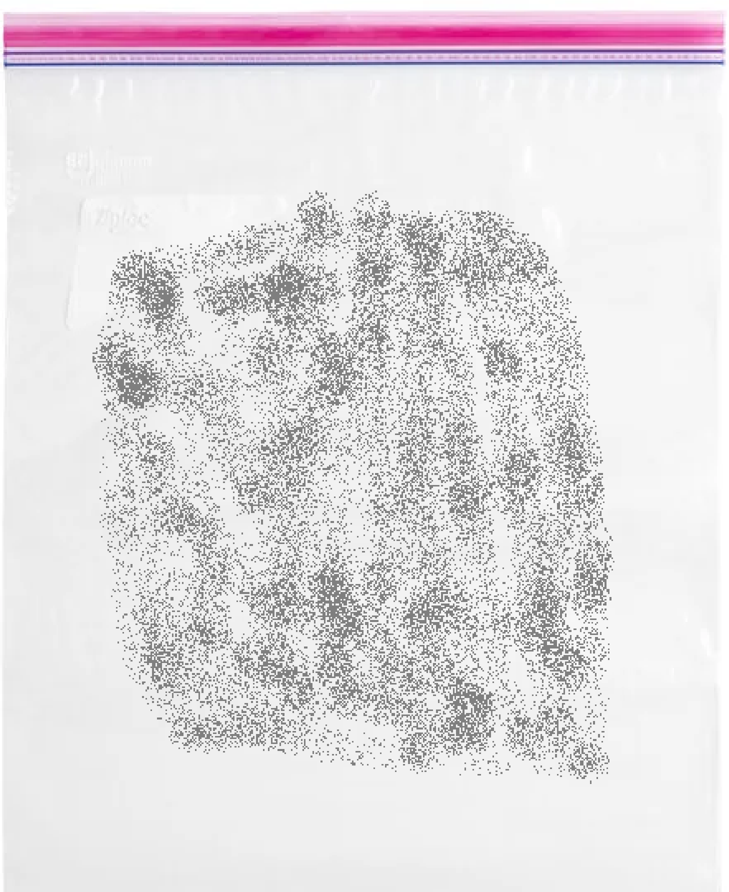


Station #6: Iron Filing Magnetic Field

☠️ DO NOT OPEN THE BAG! ☠️

Iron filings can be hazardous if ingested or inhaled

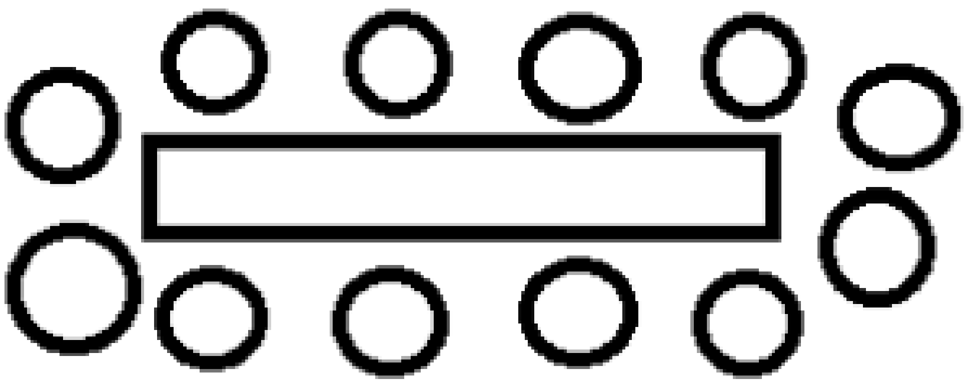
First, lay the plastic bag on the table and gently shake it so that there is a thin layer of iron filings spread out in the bag. Then, place the bar magnet on top of the bag in the middle. The iron filings will rearrange themselves! Draw the pattern the filings make on your companion sheet



Station #7: Compasses & Magnetic Fields

Arrange the compasses in a rectangular pattern

Please do not remove any of the compasses!



Station #8: Professional Profiles

These profiles are class copies! Please do not write or draw on them :)

Professional Profile: Dr. Melanie Morrison, Neuroimaging Scientist

Adapted from https://www.iamascientist.info/melanie-morrison

“What I Do

I do research to help doctors improve a type of brain surgery called deep brain stimulation (DBS). DBS sends tiny electrical signals into the brain to help treat conditions like Parkinson’s disease, which affects movement and muscle control. My work focuses on using detailed brain scans, using a technology called MRI (Magnetic Resonance Imaging), to help doctors figure out which patients are good candidates for the surgery, and to make the treatment as safe and effective as possible.”

“**How I Do It**

Before the surgery, we take detailed pictures of the patient’s brain using MRI. These images show us the brain’s health and help predict whether the patient will benefit from deep brain stimulation (DBS). The images also help the brain surgeons see their surgical targets better. What makes this work really exciting is that my team and I are directly helping patients and we’re allowing doctors to make better use of MRI in the operating room and also in the clinic. MRI machines are giant magnets, so they usually can’t be used near metal surgical tools. To solve this, at UCSF we’ve designed a MRI-safe surgery room—everything from anesthesia carts to instruments—that won’t interfere with the machine. In some surgeries, we position the patient’s head inside the MRI scanner, allowing us to collect real-time images while the surgery is happening. During DBS surgery, these live images are crucial. They help us find tiny, iron-rich areas in the brain—structures that are just a few millimeters wide and are key to treating Parkinson’s disease. The MRI guides the surgical team to place the electrodes (the tiny wires that deliver electrical signals) exactly where they need to go. Having this level of precision makes the surgery safer and increases the chances of better outcomes for the patient.”

Professional Profile: Bayan Mashat, Video Game Developer

Adapted from https://www.iamascientist.info

"Using my Imagination

I grew up in Jeddah, Saudi Arabia. I was increasingly interested in designing games. In Saudi Arabia, many of the resources I wanted weren't available or they were really expensive, but I was determined to find a way to learn what I needed.

When I was invited to the International Science and Engineering Fair, it was a big deal! I continued to win national coding competitions and was invited to the 'World Cup' of coding competitions sponsored by FIRST LEGO League."

"Becoming an Entrepreneur

Now I work in a role designed for me, where I get to use my creativity and game design skills to collaborate with others and make games. I finally launched my own indie game design studio called "Blue Tango Street". I do everything from coding, to writing software, to support roles. Entrepreneurship is not for everyone, but it's important for people who love stories, games, and coding to know that it's an option! 've learned that entertainment is a valuable part of life, and that science, engineering, and entertainment can go hand-in-hand."

Professional Profile: Alexander Bennett, Mechanical Engineer

Adapted from https://www.iamascientist.info

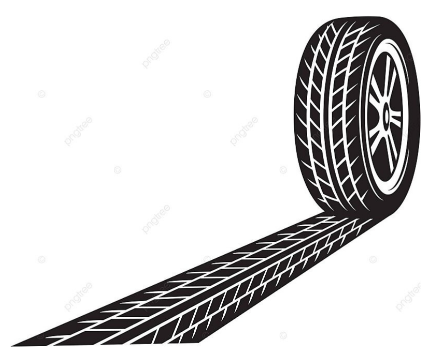
Sitting at a Crossroad

In my freshman year of college, I tried out for the super competitive University of Florida football team, and made it. I juggled both football and my engineering degree for two years, and during that time my team won the NCAA National Football Championship. It was amazing, but balancing football with my increasingly complex engineering classes was a huge challenge, so I decided to leave the team. Shortly after, I got an engineering internship with Rolls Royce, but during my time there all I got assigned was really boring to me. It made me wonder why I was even going to university if this was the type of job I'd be stuck with because of my degree.

Choosing to Continue My Education

By the end of my internship, I discovered that the people doing the work I was interested in at Rolls Royce, like designing cars, nearly all had PhDs. So, if that's the kind of work I wanted to do, it seemed like that's the kind of education I needed to get...

Connecting Engineering with Biology



My PhD research originally focused on studying the effect of friction on tire rubber. In doing so, I developed two instruments, one of which measured how much heat was transported into the rubber as it rubbed against different materials. My instrument worked so well that the tire manufacturing company Michelin actually wanted one! Alongside my tire project, I also built a 3D printer that made 3D models of cancer cells. This was when I realized that I could use the skills I've obtained as a mechanical engineer to study biological systems.