Electromagnets, Generators, and Motors

NGSS: MS-PS2 Motion and Stability: Forces and Interactions

Overview:

Students will work in pairs over four class periods to construct and test electromagnets, motors, and generators using the engineering design process. They will explore ways to make their prototypes more productive in terms of electricity, motion, and magnetism produced. Finally, students will compare and contrast the magnetism/electricity/kinetic energy conversions involved in the prototypes.

NGSS:

MS-PS2-3: Ask questions about data to determine the factors that affect the strength of electric and magnetic forces
MS-PS2-5: Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

Lesson Objectives:

- By the end of this lesson, students will use the engineering design process to accurately students construct prototypes of electromagnets and motors that function correctly.
- Students will compare/contrast the electricity/magnetism/kinetic energy conversion by accurately drawing and labelling diagrams of the electromagnet, motor, and the generator and using arrows to indicate the conversions.
- Students will explain what increases or decreases the strength of the electromagnets, motors, and generators by writing conclusion paragraphs at the end of their explorations.

Assessment and Evaluation

- Student will show mastery of how to increase/decrease the strength of electromagnets, motors, and generators by writing conclusion paragraphs at the end of each exploration.
- Students will complete a diagram in which they will draw and label an electromagnet and draw arrows indicating the electricity/magnetism conversion.
- Students will complete a diagram in which they will draw and label a generator and draw arrows indicating the electricity/magnetism conversion.
- Students will complete a diagram in which they will draw and label a motor and draw arrows indicating the electricity/kinetic energy conversion.
- Students will show that that they can compare and contrast the electromagnet, motor, and the generator by completing the “Survival Scenarios” at stations.
- Students will complete a small quiz in which they will answer questions about what the parts are of a functional electromagnet and a generator and conceptual questions about why and how they function.

Lesson created by Jennifer Moylan, Powell Middle School, Knoxville TN

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Materials:

Smartboard and Smart Notebook presentation
Cardboard
Copper wire
Ceramic bar magnets
Iron nails (2)
2 D batteries
Paperclips
Electromagnet Exploration handout
Generator Exploration handout
Motor Exploration handout
Survival Scenarios station activity handout

Procedures:

Day One:

1. Using the bell ringer as a jump off point, access prior knowledge about how a magnet works and how we can make a temporary magnet. (Students have previously learned that you can physically line up the domains in an iron nail to cause it to become a temporary magnet.)
2. Introduce electromagnetism by telling the students that there is a better, much more powerful and useful way to create a temporary magnet.
3. Show basic explanation video: https://www.youtube.com/watch?v=uMdKqQaFSmk
4. Show a picture on the Smart board of an electromagnet and ask students to draw it and explain how they think it works in partners.
5. Have students share out in partnerships how they think the electricity in the battery is converted to magnetism in the nail.
6. Give students (in pairs) the materials necessary to construct a basic electromagnet.
7. Students will then test their prototypes by trying to pick up as many paper clips with their electromagnets as possible.
8. Then give students the “Electromagnet Exploration” sheet and give them time to test two different variables to determine which one (size of battery or number of wire coils) effects the strength of their electromagnets the most.
9. In a whole class group, discuss the students’ findings about what made their electromagnets stronger.
10. Students will conclude the exploration by writing their conclusions paragraphs.
11. Students will complete a “Ticket out the Door” that asks them to draw the electromagnet and label the parts and draw arrows to show the electricity/magnetism conversion involved.

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Day Two:

1. Begin this lesson with the bellringer, “Explain how an electromagnet converts electricity to magnetism.”
2. Then discuss and draw out and label an electromagnet and how it converts electricity to magnetism.
3. Introduce the idea of a generator by telling students that there is something that works in the opposite way of an electromagnet that is very useful. Discuss with students the importance of generating electricity.
4. Show students a picture of a small generator and discuss the parts and how it works.
5. Give students the materials necessary to construct a working generator. Give them the “Generator Exploration” with the procedure to help them.
6. Students will then use the engineering design process to build and test the generator in groups of 4.
7. Students will write a conclusion paragraph at the end of the exploration.
8. We will discuss how and why the generator works and what makes it work better.
9. Students will draw and label a generator and draw arrows that illustrate the conversion between magnetism and electricity.
10. Electromagnet/generator mini quiz.

Day Three:

1. Begin this lesson with the bell ringer questions: “Explain how a generator uses magnetism and kinetic energy to produce electricity.” And “Explain how you used the steps of the Engineering Design Process to build and modify your generator. What were some modifications that you had to make to your prototype??”
2. Have a whole class discussion about how the Engineering Design Process was used and what modifications were necessary and what energy conversions were made.
3. Tell students that there is a machine that you can use that will do the opposite of a generator. Ask students to tell you what the opposite conversion will be. Ask them what the machine is called and give them hints until they get it. A motor! Engage students in a discussion about the uses of motors and how they work.
4. Use the Smartboard lesson to draw and explain what parts a basic motor must have and how the parts work. Students will take notes on their notes sheets.

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Day four:

1. Begin this lesson with the bell ringer, “Create a graphic organizer that compares and contrasts electromagnets, generators, and motors”. Engage students in a whole class discussion about the bell ringer.
2. Hold up one each of the students’ prototypes and question students about the necessary parts of each machine and how it works.
3. Explain to students that they will now use what they have learned about producing electricity, magnetism, and kinetic energy (motion) to survive on a desert island.
4. Read the scenario, “Your small airplane malfunctioned and crashed onto a remote island. You are stuck with your granddad (who thinks he MacGyver) and the two of you have to survive on your own. Your granddad is very good at constructing contraptions. He just needs you to use your knowledge about electricity and magnetism concepts to help him decide what he needs to construct.
5. Explain to students how to do the “Survival Scenarios” station activity. (activity attached)
6. Discuss the activity.
7. As exit ticket, have students draw, label, and describe energy conversions for an electromagnet, a generator, and a motor.

Closure

We will close each lesson by looking at one of our prototypes, identifying the necessary parts, and as a whole class we will explain how the electricity/magnetism conversion occurs.

Links

https://www.differencebtw.com/difference-between-electricity-and-magnetism/
https://www.slideshare.net/makadelhi/electricity-and-magnetism-basic-concepts
https://www.youtube.com/watch?v=uMdKqQaFSmk

Name:_____

Electromagnet Exploration

Directions: Use the steps of the Engineering Design Process to create a strong electromagnet.

ASK the question: How do I make a strong electromagnet?

BRAINSTORM the best way to make a strong electromagnet and write some ideas down below:

_____

_____

_____

PLAN: Make a sketch of the prototype for the electromagnet you will build

CREATE: Construct the electromagnet using the instructions provided below:

1. Wrap the copper wiring around the nail 5 times, leaving plenty of wire available on each side.
2. Attach each of the two ends of the wire to the positive and negative lodes of the D battery.
3. See how many paperclips you can pick up and write it down in table one.

Name:_____

Electromagnet Exploration

IMPROVE: Using one variable at a time, try to improve the strength of your electromagnet. First, test for different numbers of coils to see how many paperclips you can pick up and fill out table 1 with your results. Then, test a different type of battery to see how many paperclips you can pick up and fill out table 2. Compare your results.

Remember that you can only test one variable at a time!!!! That means that you have to have the same number of coils on the nail for your tests on both batteries!!

Results

Table 1: Variable #1 **Number of coils**

Number of coils around nail	Number of paperclips picked up
5	
10	
15	
20	
25	
30	

Table 2: Variable #2 **Type of battery**

Type of battery	Number of paperclips picked up
AA battery (with 30 coils)	
D battery (with 30 coils)	

Name:_____

Summary of Your Discoveries

Write a short explanation of what you have discovered during your investigation. Refer back to your illustration when necessary. Be as specific as possible.

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Name:_____

Review Questions

1. Look at tables 1 and 2. What variable caused the most amount of paperclips to be picked up and how many did it pick up? _____

2. According to your test results, what should you do to an electromagnet to make it as strong as possible?

   _____

   _____

   _____

   Why did you need to test just one variable at a time?

   _____

   _____

   _____

3. What are two things that you could have done that would have made this experiment invalid?

   _____

   _____

   _____

4. How is the Engineering Design Process similar to the Scientific Method?

   _____

   _____

   _____

5. How is it different?

   _____

   _____

   _____

6. If you only have one type of battery, what is the best way to make your electromagnet stronger?

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Name:_____

Generator Exploration

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ASK the question: How can I build a device that converts magnetism into usable electricity?

BRAINSTORM Brainstorm devices (Write down at least 3 ideas here.)

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PLAN: Make a sketch of the prototype for the generator you will build

Name:_____

Generator Exploration

CREATE: Construct the generator using the instructions provided below:

Materials

- Cardboard
- Wire-strippers
- Wire (enamel coated copper wire #30)
- Hot glue
- 1.5v bulb (LED or conventional)
- multimeter

Things that the teacher will need to do beforehand:

1. **Cut the cardboard.** Cardboard will serve as the frame and support for your simple generator. Use a ruler to measure a cardboard strip that is 8 centimeters (3.1 in) by 30.4 centimeters (12.0 in). Cut this strip out with scissors or a utility knife. This single piece will be folded to form the frame.

2. **Slide the metal shaft through the support frame.** Push a nail through the center of the cardboard frame. Make sure you go through all three pieces of cardboard that are folded into the center. This will create the hole for your shaft. You can now insert a metal shaft, or use the nail as your shaft.-The metal shaft does not have to be anything in particular. Any piece of metal that will fit through the hole and come all the way out the other side of the frame is acceptable. The nail you use to make the hole will work perfectly.

3. **Strip the ends of the wire.** Use a knife or a wire stripper to remove the insulation from each end of the wire. Remove about 2.54 centimeters (1.00 in) of insulation from each side. This will allow you to connect the wire to an electronic device.

4. **Glue the magnets to the shaft.** Use hot glue to glue four ceramic magnets to the shaft. You want the magnet to be stationary with respect to the shaft. The magnets should be glued onto the shaft after the shaft has been inserted into the frame. Allow the glue to dry for several minutes (the instructions on the container can tell you exact drying times for your type of glue).

Name:_____

Generator Exploration

Students will:

1. **Wind the copper wire.** Make several turns around the cardboard box with enamel coated copper wire (#30 magnet wire). Wind 200 feet (61 m) of wire as tight as you can. Leave about 16 to 18 inches (40.6 to 45.7 cm) of wire loose on each end to connect to your meter, light bulb, or other electronic device. The more "turns" or winds you make around the cardboard frame, the more power your generator should produce.

2. **Connect the wires to an electronic device.** Attach the two wires you have loose at the ends of the windings to a red LED or a 1.5V grain-of-wheat lamp. Or, connect the test leads from an AC voltmeter or multimeter to them. Keep in mind that you are producing a very low voltage, and larger devices (e.g. a regular light bulb) will not be powered by this generator.

3. **Turn the shaft with your fingers.** This allows you to see if the ends of the magnets hit the inside of the frame. The magnets must turn freely, but as close as possible to the walls of the frame. Again, having the magnet's ends as close to the copper wire windings as possible will increase the "exciting" action of the magnetic fields the magnet produces.

TEST: Collect data

	One lightbulb	Two lightbulbs
Clockwise		
Counter clockwise		
Alternating clockwise and counter clockwise		

Name:_____

Summary of Your Discoveries

Write a short explanation of what you have discovered during your investigation. Refer back to your illustration when necessary. Be as specific as possible.

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Name:_____

Motor Exploration

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ASK the question: How can I build a device that converts electricity into usable kinetic energy (motion)?

BRAINSTORM Brainstorm devices (Write down at least 3 ideas here.)

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PLAN: Make a sketch of the prototype for the motor you will build

Name:_____

Motor Exploration

CREATE:

1. Starting in the center of the wire, wrap the wire tightly and neatly around the marker 30 times.
2. Slide the coil you made off of the marker.
3. Wrap each loose end of the wire around the coil a few times to hold it together, then point the wires away from the loop.
4. Ask an adult to use the hobby knife to help you remove the top-half of the wire insulation on each free end of the coil. The exposed wire should be facing the same direction on both sides. *Why do you think half of the wire needs to remain insulated?*
5. Thread each loose end of the wire coil through the large eye of a needle. Try to keep the coil as straight as possible without bending the wire ends.
6. Lay the D battery sideways on a flat surface.
7. Stick some modeling clay on either side of the battery so it does not roll away.
8. Take 2 small balls of modeling clay and cover the sharp ends of the needle.
9. Place the needles upright next to the terminals of each battery so that the side of each needle touches one terminal of the battery.
10. Use electrical tape to secure the needles to the ends of the battery. Your coil should be hanging above the battery.
11. Tape the small magnet to the side of the battery so that it is centered underneath the coil.

TEST

What happens?

What happens when you spin the coil in the other direction?

What happens with a bigger magnet?

A bigger battery?

Thicker wire?

Conclusions:

Name:_____

Summary of Your Discoveries

Write a short explanation of what you have discovered during your investigation. Refer back to your illustration when necessary. Be as specific as possible.

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Name:_____

Survival Scenarios (Teacher Copy)

Directions: For each survival scenario, carefully consider what force or energy you need and choose a machine to use. You may choose to use an electromagnet, a motor, or a generator. Write down what you will use and why. Then draw a model of that machine.

Your predicament:
Your small airplane malfunctioned and crashed onto a remote island. You are stuck with your granddad (who thinks he is Mcguyver) and the two of you have to survive on your own. Your granddad is very good at constructing contraptions. He just needs you to use your knowledge about electricity and magnetism concepts to help him decide what he needs to construct.

Parts available:
Batteries
Copper wire
Magnets
Small light bulbs
Nails

Scenario 1: The airplane is in pieces all over the beach. Your granddad has decided to try and construct small survival gadgets as well as possibly a boat out of the small metal pieces that have been dispersed. What gadget could your granddad construct to accomplish this?
Electromagnet - You need magnetism to pick up metal and an electromagnet converts electricity to magnetism.

Scenario 2: You have built a tree house and now you want lights in it. What do you need to construct?
Generator - We need electricity to power lights. A generator converts magnetism and/or motion to electricity.

Scenario 3: You want to build an elevator to lift your granddad up to the tree house (he is too old to climb☹.) What could you use to cause the ropes to move and lift a platform?
Motor - We need motion (kinetic energy) to lift the platform. A motor converts electricity and magnetism to motion.

Scenario 4: It is soooo hot on this island! How could you build a fan for the tree house?
Motor - You need motion. A motor converts electricity and magnetism to motion.

Name:_____

Survival Scenarios (Teacher Copy)

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Scenario 5: You have a small video camera and have constructed a small remote control vehicle to navigate the difficult to reach parts of the island to see if they hold enough food sources to make the trek worthy for you to take. What do you need to make your vehicle move?

Motor - You need motion. A motor converts electricity and magnetism to motion.

Conclusion: Explain how each machine works and how it is useful.

Motors, electromagnets, and generators are all useful because they convert one type of force or energy into another. So, depending on what you need at the time you can use any machine or more than one. If you need magnetism you should construct an electromagnet. This is very useful because you can turn the magnetism on and off and control the amount of magnetism by using more or less electricity (battery) or changing the amount of coils around the nail. If you need electricity you can use a generator. There are different types of generators depending on what materials you have available, but you can use magnetism and kinetic energy. If you need motion then you can make a motor which converts electricity from a battery and magnetism to kinetic energy.

Name:_____

Survival Scenarios

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Parts available:

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Name:_____

Survival Scenarios

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Scenario 2: You have built a tree house and now you want lights in it. What do you need to construct?

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Survival Scenarios

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Name:_____

Survival Scenarios

Conclusion: Explain how each machine works and how it is useful.