7 Magnetism and Electricity At-a-Glance:

In the last unit, students analyzed how structures have to be able to withstand all of the forces that act on them. In this unit, students focus on electric and magnetic forces. Students investigate the interactions between positively and negatively charged materials. Students build on their understanding with an investigation into magnetism, and then design a prototype that solves a problem using magnets.

Common Misconceptions:

- **Misconception**: All metals are attracted to magnets.
  - ✓ **Fact**: Not all metals are attracted to magnets. Iron, cobalt, and nickel are the three naturally occurring metals that are attracted to magnets.
- **Misconception**: Larger magnets are always stronger than smaller magnets.
  - ✓ **Fact**: A magnet's strength depends on the materials that make it up. With two magnets of the same material, the larger magnet will be stronger than the small magnet. But in magnets made up of different materials, the smaller magnet may actually be stronger than the larger magnet.

A Breakdown of the Lesson Progression:

1 Static Charge

In the first lesson, students build on their knowledge of forces by exploring electric forces. They analyze how materials can become either positively or negatively charged, and then use an electroscope to explore how opposite charges are pulled toward one another and like charges are pushed away from one another.

2 Magnets and Magnetic Fields

Students continue to explore attractive and repulsive forces, focusing in this lesson on magnets. Students use iron filings to visualize the magnetic field interactions of permanent magnets and then test different-sized magnets.

3 Engineering Pick-and-Place Devices

In the third lesson, students apply what they know about magnetic interactions to engineer a device that can pick up and place metal paper clips for a metal factory.

Unit 7: Magnetism and Electricity

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Unit 7:

Magnetism and Electricity

Unit Overview:

Joseph Dwyer is a physicist who studies lightning. Lightning happens because of the attractive force between positively and negatively charged materials. One day, Dwyer was on a plane that accidently flew through the middle of a thunderstorm. The plane plummeted 914 meters (3,000 feet) while violently rolling back and forth.

Joseph Dwyer, professor of Physics and Space Sciences at the Florida Institute of Technology and director of the Geospace Physics Lab

Although many people would be afraid, Dwyer also saw an opportunity. "The whole event lasted just a couple of minutes, but we got a goldmine of data while inside that thunderstorm," Dwyer said in an interview with the Academic Minute.

In this unit, students explore how materials can become electrically charged and then attract or repel other materials without touching them. They then investigate how magnets can attract or repel certain objects within their magnetic field, and use that knowledge to engineer a solution to a problem using magnets.

Unit Goals:

1. Explain how materials can become electrically charged, and how they interact with other charged substances.
2. Describe the relationship between a magnet's magnetic field and the attraction/repulsion of other magnetic materials.
3. Apply scientific knowledge of magnetic forces to design a technology that uses magnets to attract or repel other objects.

Applying Next Generation Science Standards

This unit covers the following **Next Generation Science Standards**. Each standard includes where it is found in the unit, as well as how it applies the relevant crosscutting concepts (listed in green) and disciplinary core ideas (listed in orange). **Note: Science and engineering practices are listed separately.*

Grade-Specific Standards:

3-PS2	Motion and Stability: Forces and Interactions
3-PS2-3.	**Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.** ▪ **Types of Interactions:** In the first lesson, students continue their exploration of forces with a focus on electric forces, exploring the attractive/repulsive nature of these forces. In the second lesson, students continue to evaluate attractive/repulsive interactions by investigating magnetic interactions. In the third lesson, students apply what they know about magnetic interactions to engineer a prototype that uses magnets to solve a problem. <u>Lessons 1, 2, and 3</u> ▪ **Cause and Effect:** Students analyze the cause-and-effect relationship of electric and magnetic forces. <u>Lessons 1, 2, and 3</u>
3-PS2-4.	**Define a simple design problem that can be solved by applying scientific ideas about magnets.** ▪ **Types of Interactions:** Students apply their scientific knowledge of magnets to design a solution that uses magnets to pick up and move metal clips from one station to another in a short amount of time. <u>Lesson 3</u> ▪ **Interdependence of Science, Engineering, and Technology:** Students use what they have learned about magnetic interactions between materials to help them engineer a technology that can solve a specific problem they've defined. <u>Lesson 3</u>

3-5-ETS1	Engineering Design
3-5-ETS1-1.	**Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.** ▪ **Defining and Delimiting an Engineering Problem:** Students use information they've been given to define a problem: a factory needs a magnetic device to help its workers move metal clips from one station to another in less time. Lesson 3 ▪ **Influence of Engineering, Technology, and Science on Society and the Natural World:** Students describe how engineers identify different problems that society faces, and then use scientific knowledge to design technologies that solve those problems. Lesson 3
3-5-ETS1-2.	**Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.** ▪ **Developing Possible Solutions:** Students come up with different possible design solutions that address the factory's need, and then decide on the one they think has the best chance of meeting the criteria of the problem within the constraints. Lesson 3 ▪ **Influence of Engineering, Technology, and Science on Society and the Natural World:** Students analyze how well their prototype device solves the problem and addresses the constraints of the problem. Lesson 3
3-5-ETS1-3.	**Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.** ▪ **Optimizing the Design Solution:** Students test their prototype to see how well it moves paper clips from one place to another in 10 seconds or less. Students evaluate possible failure points of their design and areas it can be improved. Lesson 3 ▪ **Cause and Effect:** Students connect the materials used and the structure of their prototypes with their effectiveness at solving the problem within the constraints. Lesson 3

Supporting Standards:

5-PS1	Matter and Its Interactions
5-PS1-1.	**Develop a model to describe that matter is made of particles too small to be seen.** ▪ **Structure and Properties of Matter:** Students use a model of an atom to explore how the number of protons and electrons in a material determines its charge. Lesson 1 ▪ **Scale, Proportion, and Quantity:** Students describe the relationship between the atomic structure of matter and static charge. Lesson 1
5-PS1-3.	**Make observations and measurements to identify materials based on their properties.** **Students focus on the properties of electrical conductivity and magnetism in this unit.* ▪ **Structure and Properties of Matter:** In the first lesson, students compare electrical conductors and insulators, using what they know about atoms and electrons to support their comparisons. In the second lesson, students explore the property of magnetism, investigating the shape and strength of different magnets' magnetic fields. In the third lesson, students classify the available materials according to their properties. Lessons 1, 2, and 3 ▪ **Scale, Proportion, and Quantity:** In Lessons 1 and 2, students use what they know about matter at the atomic scale to describe the properties of electrical conductivity and magnetism. In Lesson 3, students make observations of different materials to help them decide which materials would be best in their prototypes. Lessons 1, 2, and 3

Science and Engineering Practices

Students use the following science and engineering practices in the unit's lessons.

Lesson 1: Static Charge

1. Asking questions (for science) and defining problems (for engineering)

- Students investigate the focus question: "Will materials with a high static charge cause the foil sheets in your electroscope to move farther apart compared to materials with a low static charge?"

2. Developing and using models

- Students build a model electroscope to help them answer the focus question of the investigation.

3. Planning and carrying out investigations

- Students use their electroscope model to measure the electric force produced by the static charge of different materials when those materials are rubbed with wool.

4. Analyzing and interpreting data

- Students collect and analyze data on the electric force produced by different materials rubbed with wool, as measured by the distance created between two foil sheets.

5. Using mathematics and computational thinking

- Students measure and record the distance between the foil sheets on the electroscope with a ruler and then compare the measurements from each material.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use the data they gathered in their investigation to construct an explanation about the relationship between the amount of static charge a material has and the electric force it produces.

7. Engaging in argument from evidence

- Students come together as a class to present their analysis and to compare their analysis with other student teams, evaluating reasons for possible differences and using their analysis to support their argument.

8. Obtaining, evaluating, and communicating information

- Students use information from their readers, class dialogue, and investigation results to communicate about how electric forces cause motion without objects having to come into contact with one another.

Lesson 2: Magnets and Magnetic Fields

1. Asking questions (for science) and defining problems (for engineering)

- This lesson has two investigations. In the first investigation, students explore the focus questions: "What does the magnetic field of a bar magnet look like?" and "What "How do the magnetic fields of attracting magnets compare to the magnetic fields of repelling magnets?"
- In the second investigation, students explore the focus question: "Does the size of a ceramic magnet affect how far away it can attract paper clips? "

2. Developing and using models

- In the first investigation, students create visual models (scientific diagrams) of the magnetic fields of attracting and repelling magnets.

3. Planning and carrying out investigations

- Students work in teams as they carry out each of the investigations. In the first investigation, students use iron filings to trace the shape of the magnetic fields around different magnets to investigate the questions.
- In the second investigation, students test ceramic magnets of different sizes to investigate the question.

4. Analyzing and interpreting data

- In the first investigation, students collect and analyze observational data about the magnetic fields around different magnets.
- In the second investigation, students record how far the magnet was from the paper clip when it was pulled by the magnet.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use the data they gathered in their investigations to construct an explanation about how magnetic forces act on different objects.

7. Engaging in argument from evidence

- Students come together as a class to present their analysis and to compare their analysis with other student teams, evaluating reasons for possible differences and using their analysis to support their argument.

8. Obtaining, evaluating, and communicating information

- Students use information from their readers, class dialogue, and investigation results to communicate about how magnetic forces cause motion without objects having to come into contact with one another.

Lesson 3: Engineering Pick-and-Place Devices

1. Asking questions (for science) and defining problems (for engineering)

- Students use information from a scenario to help them define the main problem facing a factory, which needs engineers to design a device that must use magnets to lift and move as many metal clips as possible from one station to another in 10 seconds or less. Students identify the criteria and constraints of the problem.

2. Developing and using models

- Students create a visual model (scientific diagram) of their pick-and-place prototype. Students use their diagram as a guide for constructing a physical model of their prototype.

3. Planning and carrying out investigations

- Students work in teams to come up with possible solutions to solve the problem. Once they have built a prototype, they carry out a procedure for testing it to see how well it solves the problem.

4. Analyzing and interpreting data

- Students collect and analyze data on how well their pick-and-place prototype picked up paper clips and moved them to a new location, using their data to identify possible failure points that they can improve upon.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use the data they gather from their first prototype solution to improve their second prototype so that it better solves the problem. They do this for up to three prototypes.

7. Engaging in argument from evidence

- Students use the data and observations from their prototypes to describe how well their prototype solved the problem given the criteria and constraints of the problem, how their modifications positively or negatively affected their prototype's ability to pick up and place paper clips in under 10 seconds, and to decide if they would refine or replicate any of their designs based on the data.

8. Obtaining, evaluating, and communicating information

- Students use the data they collected from their testing to communicate about how well their prototype solved the problem presented in the scenario. They use information from the student reader, class dialogue, and previous investigations to communicate about how magnets can be used to solve problems.

Unit 7 Pacing Guide Example

All KnowAtom units are designed to take approximately one month. Lessons may span one or two weeks. This pacing guide provides one example for how to break down the lessons in this unit over a month. **Breakdown is based on 30- to 45-minute class periods.** Communities that have longer class periods or schedules where science class occurs more frequently can modify this guide accordingly.

Any days in this guide that appear unused take into account months with holidays, vacations, times when an experiment, engineering, and/or investigation takes longer to complete, and/or days when science class does not occur. Note that at the beginning of the school year, when the engineering and scientific processes are new to students, experiments and engineering activities may take an extra class period to complete.

Unit 7: Magnetism and Electricity				
Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Week 1				
Lesson 1 **Start:** As a class, read Section 1 of the KnowAtom student reader. **Final Goal:** Transition to the Socratic dialogue.	**Lesson 1** **Start:** Socratic dialogue. **Final Goal:** Transition to the Static Charge Investigation.	**Non-Science Day**	**Lesson 1** **Start:** Teams assemble and test their electroscopes. **Final Goal:** As a class, wrap up the lesson and debrief.	**Non-Science Day**
Week 2				
Lesson 2 **Start:** As a class, read Section 2 of the KnowAtom student reader. **Final Goal:** Transition to the Socratic dialogue.	**Lesson 2** **Start:** Socratic dialogue. **Final Goal:** Transition to the Magnetic Fields Investigation 1.	**Non-Science Day**	**Lesson 2** **Start:** Teams carry out Magnetic Fields Investigation 1. **Final Goal:** As a class, share observations and wrap up Investigation 1.	**Non-Science Day**

Week 3				
Lesson 2 **Start:** Teams carry out Magnetic Fields Investigation 2. **Final Goal:** As a class, share results/ observations and wrap up lesson.	**Non-Science Day**	**Lesson 3** **Start:** Socratic dialogue. **Final Goal:** Transition to engineering investigation scenario/problem.	**Non-Science Day**	**Lesson 3** **Start:** Students carry out the first part of the engineering investigation. **Final Goal:** Students complete the problem through the materials survey steps of the engineering investigation.
Week 4				
Non-Science Day	**Lesson 3** **Start:** Students complete possible solutions, diagram and build prototype, and test. **Final Goal:** Students collect test data for Prototype 1.	**Lesson 3** **Start:** Students modify and test Prototypes 2-3 **Final Goal:** Students collect test data for Prototype 3.	**Lesson 3** **Start:** Students complete the refine and replicate portion of the engineering investigation. **Final Goal:** As a class, share results, wrap up the engineering investigation and de-brief.	**Non-Science Day**

Science Words to Know:

Use the blank concept map visual to connect vocabulary once the unit is complete. An example concept map is displayed in Appendix 3.

1. **attract** – to pull together

2. **electric conductor** – a material that electrons can easily pass through

3. **electric insulator** – a material that electrons cannot pass through easily

4. **magnet** – an object that produces a magnetic field; has a north and south pole; attracts or repels other magnets or magnetic materials such as iron

5. **magnetic field** – the area around a magnet that attracts or repels other magnets and magnetic materials such as iron

6. **permanent magnet** – an object that stays magnetized without electricity

7. **repel** – to push apart

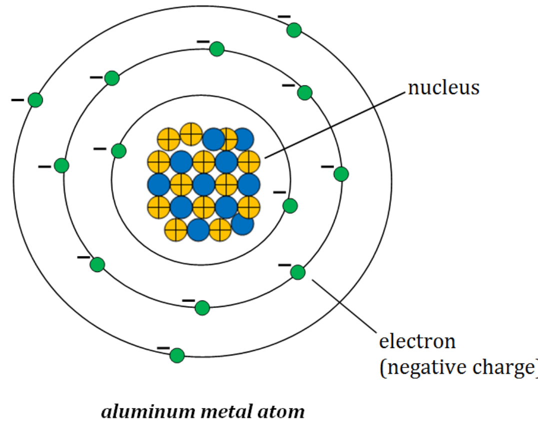
8. **static charge** – the buildup of electric charge in an object

9. **temporary magnet** – an object that acts like a permanent magnet when it is within a strong magnetic field

Teacher Background

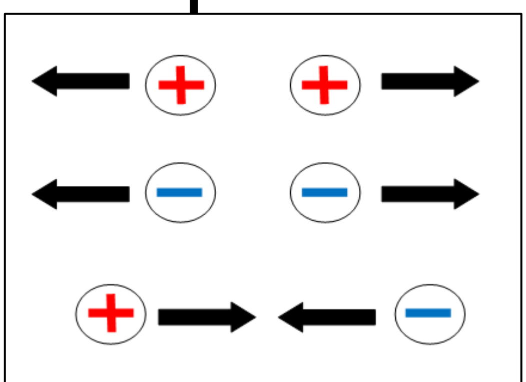
Lightning and the Structure of Matter

Although lightning strikes Earth millions of times a day, there are still many unanswered questions, including how it gets started, how it moves, and why it strikes one thing and not the other.



the structure of an atom

Scientists do know some facts about lightning, including that it is a result of interactions at the atomic scale. Remember that all of matter is made up of atoms, which are themselves made up of smaller particles called subatomic particles.



Like charges repel. Opposite charges attract.

Protons are the positively charged subatomic particles, and they are found in the nucleus along with neutrons, which have no charge. Electrons are the negatively charged subatomic particles of the atom, and they orbit the nucleus because their negative charge is attracted to the positive charge of the protons. The rule is that opposite charges attract and like charges repel. To **attract** means to pull together. To **repel** means to push apart.

The number of each subatomic particle a material has determines its electric charge. Electric charge is the property of having an imbalance of positively or negatively charged particles. A negative charge occurs when a material has more electrons than protons. A positive charge occurs when a material has more protons than electrons. The buildup of electric charge in an object is called **static charge**.

Static Charge and Attractive/ Repulsive Forces

Static charge can happen when two objects rub against each other. Because electrons are naturally attracted to positively charged materials, if a negatively charged material meets a positively charged material, the materials will attract due to their opposite charges. In some materials, electrons move from one object to the other. The material with more electrons now has a negative charge, and the material with fewer electrons has a positive charge.

Look at the picture on the right of the child at the bottom of the slide. Electrons moved from the child to the slide, causing a static charge to build up. The slide gained electrons, giving it a negative charge. The child lost electrons, giving her a positive charge.

Each strand of this child's hair has a positive charge. Because like charges repel, the hairs stand up to push away from each other.

Each of the child's hairs has the same positive charge, and these positive charges repel each other. Each piece of hair pushes away from every other piece of hair, trying to get as far from each other as possible. This is what makes the child's hair stick straight up.

Something similar happens when you take off a hat. Electrons move from your hair to the hat. Your hair gets a positive charge. This is why it sticks up.

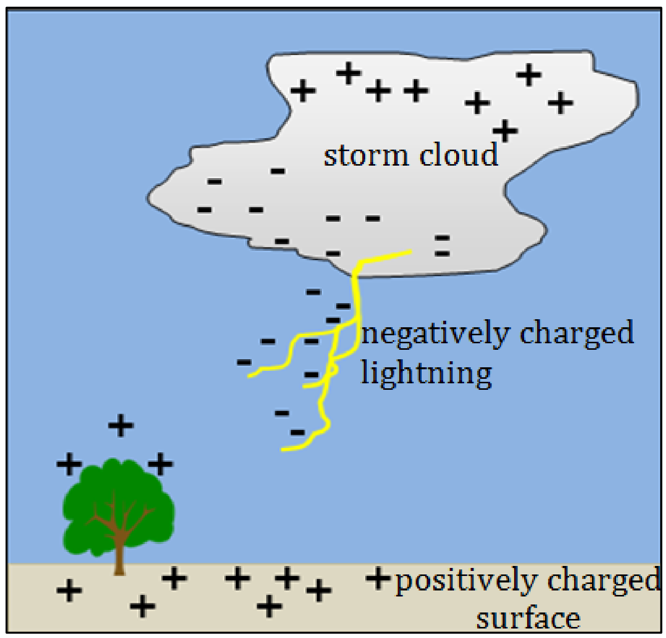
Objects with an electric charge can attract other objects without touching them. For example, if you rub a balloon against your clothes, electrons move from your clothes to the balloon, giving the balloon a negative charge. If you hold the balloon near a wall, an attractive force pulls the balloon and the wall together. If you have two negatively charged balloons, a repellant force pushes the balloons apart. The more charge an object has, the stronger force it will exert on other objects.

Static Charge and Lightning

Lightning happens when clouds get a static charge. Electrons move to the bottom of the clouds, giving the tops of the clouds a positive charge and the bottoms a negative charge.

Objects on Earth's surface below a storm cloud become positively charged. The positive charge on Earth's surface attracts the electrons. The positive charge of other storm clouds can also attract the electrons.

Electrons move from the storm cloud to the ground or to other storm clouds. We see this movement of electrons as a flash of lightning.



Lightning occurs as a result of static charge.

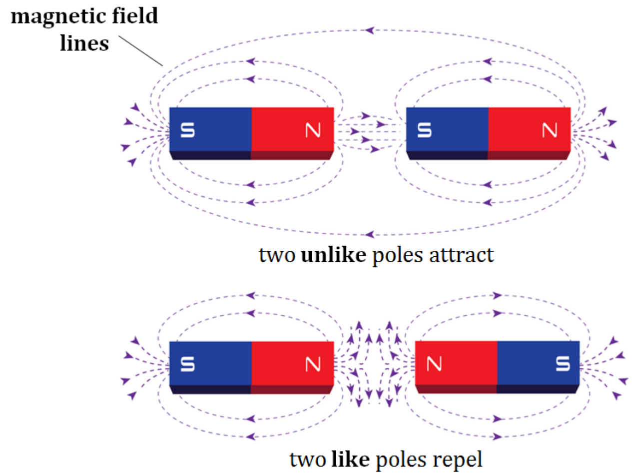
Surfaces that build up static charge are usually insulators. **Electrical insulators** don't allow electrons to pass through easily. This is how the electrons can build up in the object. Glass, rubber, plastic, and ceramic are good insulators.

Electrical conductors are materials that electrons can easily pass through. Metals are common conductors. Silver, copper, bronze, and aluminum are all metals and are good electrical conductors.

Magnetic Forces

Electric forces that attract or repel different substances aren't the only non-contact forces. Magnetic forces also act on objects without coming into contact with them.

A **magnet** is any object that produces a **magnetic field**— the area around a magnet that attracts or repels other magnets and magnetic materials such as iron. The magnetic field occurs because all magnets have two magnetic poles: a north pole and a south pole. A pole is an area of a magnet where magnetism is concentrated. The magnetic field originates at the north pole, does a loop, and then returns to the magnet's south pole.



magnetic fields

The rules of magnetism are similar to the rules of electric charge: opposite poles attract and like poles repel. This means that the north pole of one magnet always attracts the south pole of another, but two north poles or two south poles always repel.

Magnetism is caused by electrons. In non-magnets, electrons randomly spin in their orbital shells. In contrast, groups of electrons in magnets spin in the same direction. The locations of a magnet's north pole and south pole are determined by which direction its electrons are spinning. Objects such as paperclips become temporarily magnetized because their electrons spin uniformly in the presence of a magnetic field.

Magnets are useful because they can attract or repel other magnets or magnetic materials without coming into contact with the other object. A magnet in motion can also generate an electric current, which is how generators function.

Types of Magnets

Magnets are categorized by the origin of their magnetic fields. A natural magnet is a rock magnetized by Earth's magnetic field. Any rock containing iron, such as magnetite, can be a natural magnet. The rock becomes magnetized over thousands of years as the electrons of the iron particles that make up a magnetite rock begin to spin in the same direction.

Human-made magnets are created artificially and can be permanent or temporary. **Permanent magnets** are usually made of iron or steel. They are "permanent" because once they are magnetized, they stay magnetized for a very long time. The strongest kind of permanent magnets are rare earth magnets, which are made from the rare earth elements neodymium or samarium.

The magnetic field of the horseshoe magnet attracts the iron-containing nail.

In contrast, **temporary magnets** act like a permanent magnet when they are within a strong magnetic field. They lose their magnetism when the magnetic field goes away. They are created by repeatedly rubbing a metal object, such as a paper clip or iron nail, with an active magnet to align the object's electrons.

Electrical current is also capable of creating a uniform electron spin. An electromagnet is a tightly wound coil of wire that produces a magnetic field when electricity passes through the wire. The strength of the magnetic field created by the electromagnet is adjustable by changing the voltage flowing through the wire, and by increasing or decreasing the amount of coils around the iron core. Reversing the flow of electricity reverses the poles of the electromagnet.

Lesson 1: Static Charge

<u>Objective</u>: Students build and test static charge detectors (electroscopes) to observe how materials with high and low static charge exert different electric forces.

<u>Materials</u>:

Consumable

A. Goggles – 1 per student

B. "Static Charge Investigation"
– 1 per student
(student reader)

C. Cardboard bases
– shared

D. Aluminum foil
– 1 sheet per team

E. Plastic cups (10 oz)*
– 1 per team

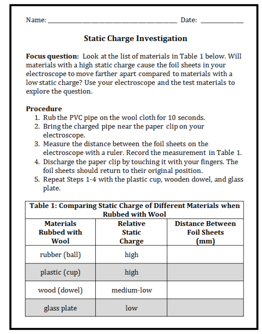
F. Large paper clips*
– 1 per team

G. Large plastic cups
(24 oz) – 1 per team

H. Non-drying clay
– shared

I. Dowels – 1 per team*

A


B


Name: ______________________ Date: __________

Static Charge Investigation

Focus question: Look at the list of materials in Table 1 below. Will materials with a high static charge cause the foil sheets in your electroscope to move farther apart compared to materials with a low static charge? Use your electroscope and the test materials to explore the question.

Procedure

1. Rub the PVC pipe on the wool cloth for 10 seconds.
2. Bring the charged pipe near the paper clip on your electroscope.
3. Measure the distance between the foil sheets on the electroscope with a ruler. Record the measurement in Table 1.
4. Discharge the paper clip by touching it with your fingers. The foil sheets should return to their original position.
5. Repeat Steps 1-4 with the plastic cup, wooden dowel, and glass plate.

Table 1: Comparing Static Charge of Different Materials when Rubbed with Wool

Materials Rubbed with Wool	Relative Static Charge	Distance Between Foil Sheets (mm)
rubber (ball)	high	
plastic (cup)	high	
wood (dowel)	medium-low	
glass plate	low	

C


D


E


F


G


H


I


Non-Consumable

J. Plastic rods (PVC) – 1 per team

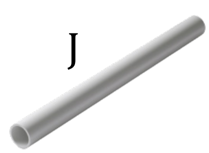
K. Glass plates – 1 per team

L. Wool cloth – 1 per team

M. Parts of an Atom Visual – (not shown)

N. Static Charge Visual – (not shown)

O. Electroscope Visual – (not shown)

J


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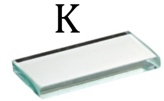

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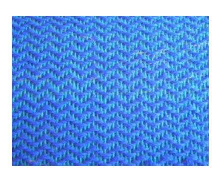


*These items are used again in Lessons 2 and 3.

Teacher Tool Kit
P. Rulers – 1 per team
Q. Hole punches – 1 per team
R. Invisible tape – 1 per team
S. Scissors – 1 per team

P

Q

R

S


Teacher Preparation:

- Download visuals from the KnowAtom Interactive website.
- Use scissors to cut the cardboard bases into 2" x 10" strips (one strip per team of two students). Teams can also cut the strips themselves during the investigation (optional).
- Arrange several pick-up stations for students to access the materials during the investigation. For example:
  - Pick-Up Station 1: cardboard/cardboard strips, large plastic cups (24 oz), large paper clips, scissors, invisible tape and rulers
  - Pick-Up Station 2: non-drying clay
  - Pick-Up Station 3: aluminum foil sheets and hole punches
  - Pick-Up Station 4: student readers, plastic rods (PVC), dowels, glass plates, and wool cloths

Student Reading Preparation:

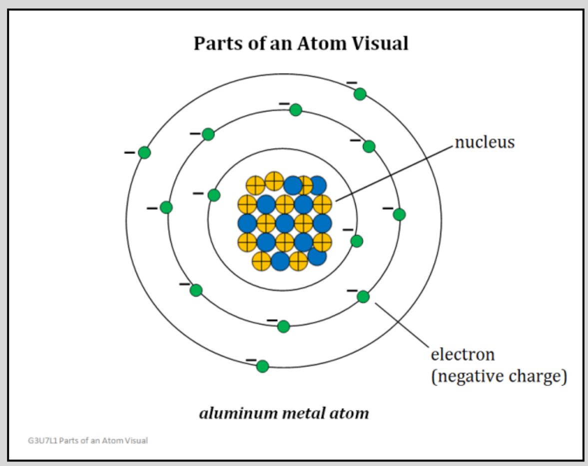
- Read Section 1 of the student reader together as a class before the Socratic dialogue and activity portion of the lesson. Model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
  - Use "why" and "how" questions to connect ideas in the reading to student experiences.

Socratic Dialogue:

- The Socratic dialogue serves as the bridge between the nonfiction reading and the lab portion of the lesson.
- The example Socratic dialogue below describes one possible progression of ideas to engage students in higher order thinking. Blocks are used to divide the dialogue according to key organizing concepts. Note that in a Socratic dialogue, the teacher is not the only one asking questions and challenging ideas. Students should be actively engaged in proposing questions, challenging assumptions, and using evidence to support their arguments. *Not sure how to set up a Socratic dialogue? Check out www.knowatom.com/socratic for an in-depth look at how to hold a next generation Socratic dialogue in the classroom.*

Block 1: Introduction to Static Electricity

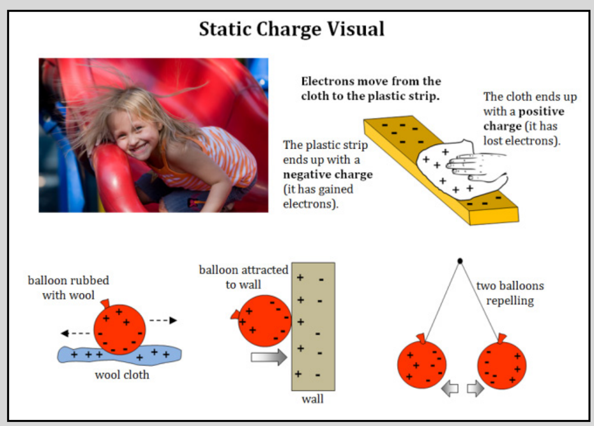
1. Display *Parts of an Atom Visual*. Begin a dialogue with students that connects the last unit, which focused on the forces that act on different structures, with this lesson, which explores electric forces that attract or repel.



- **Big Idea 1**: Coach students toward the idea that electrons have a negative charge and protons have a positive charge, and these charges interact with one another. For example:
  - *Ask one student to describe what around them is made up of atoms. (All matter is made up of atoms. Anything that is solid, liquid, or a gas is made up of atoms, which are tiny particles too small to see.)*

- *Ask another student where protons are found in an atom. (Protons are smaller parts of an atom. They are found in the nucleus.)*
- *Ask the first student where electrons are found in an atom. (Electrons are another type of particle found in an atom. Electrons orbit the nucleus.)*
- *Ask another student how protons are different from electrons. (Protons have a positive charge and electrons have a negative charge.)*
- *Ask the first student how protons and electrons interact with one another. (The positive charge of the protons attracts the negative charge of the electrons. To* ***attract*** *means to pull together. Opposite charges attract each other. This is a pulling force.)*
- *Ask another student how two electrons interact with each other. (Both electrons have the same charge (negative). Like charges repel. To* ***repel*** *means to push apart. Two negative charges push away from each other. This is a pushing force.)*

2. Display *<u>Static Charge Visual</u>*. Continue the dialogue with students about protons and electrons, focusing on **static charge**, which is the buildup of electric charge in an object.



- ☐ **<u>Big Idea 2</u>:** Coach students toward the idea that sometimes the negative charges in an object separate from the positive charges. This causes objects to have either a positive charge or a negative charge. For example:
  - *Ask one student why static charge can happen when two objects rub against each other. (When some materials rub*

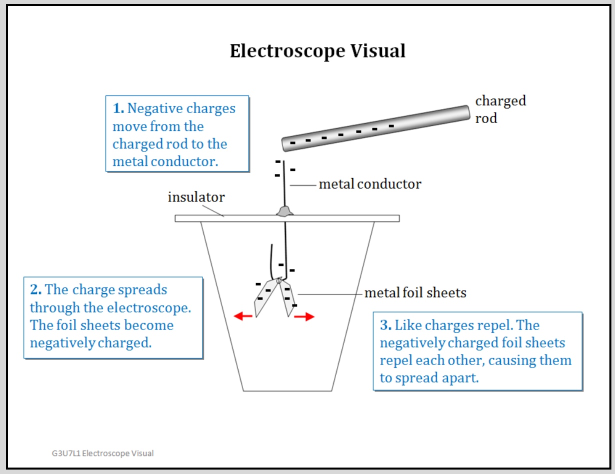
together, electrons move from one material to another. The material that loses electrons will have a positive charge. The material that gains electrons will have a negative charge.)

- *Ask another student to describe what caused the child's hair in the visual to stand straight up. (The child rubbed against the slide going down it. Electrons moved from the child to the slide. A static charge built up. The slide has more electrons, which gives it a negative charge. The child now has fewer electrons, so she has a positive charge. Each of the child's hairs has the same positive charge. These positive charges repel each other. Each piece of hair pushes away from every other piece of hair. They try to get as far from each other as possible. This makes the child's hair stick straight up.)*
- *One at a time, provide multiple students with the change to respond to this question so that students are thinking about the attractive/repulsive nature of electric forces. Redirect if misconceptions arise but provide students with the chance to question one another as they build out the answer to the question.*

- [ ] **Big Idea 3:** Coach students toward the idea that some materials are electrical conductors and others are electrical insulators. Surfaces that build up static charge are usually insulators. For example:
  - *Ask one student what makes a material an electrical conductor. (**Electrical conductors** are materials that electrons can easily pass through. Metals are common conductors. Silver, copper, bronze, and aluminum are all metals. They are good electrical conductors.)*
  - *Ask another student what makes a material an electrical insulator. (**Electrical insulators** don't allow electrons to pass through easily. Glass, rubber, plastic, and ceramic are good insulators.)*

- *Ask the first student why surfaces that build up static charge are usually insulators. (Because they don't allow electrons to pass through easily, the electrons can build up on the object.)*

3. Display *Electroscope Visual*. Transition to the investigation with a dialogue about how electroscopes are tools that can be used to measure the presence and size of electric charge on a surface.



- ☐ **Big Idea 4**: Coach students toward the idea that electroscopes work because objects with an electric charge can attract other objects without touching them. For example:
  - *Ask one student why the rod is first rubbed against another surface. (The rubbing action is what causes electrons to move from one material to another. This movement causes electrons to build up on the surface of the rod, giving it a negative charge.)*
  - *Ask another student how the negatively charged rod interacts with the two pieces of foil at the bottom of the electroscope. (The electrons from the rod move through the metal conductor to the two pieces of foil at the bottom.)*
  - *Ask the first student what they expect will happen when the electrons move from the metal conductor to the pieces of foil at the bottom. (Both pieces of foil will gain electrons. This will give them both a negative charge. Because like charges repel, the pieces of material will likely push away from each other.)*
  - *One at a time, provide multiple students with the chance to respond to this question so that students are thinking about*

static charge and the attractive/repulsive interactions that occur. There is no "right" answer here; the goal is for students to be thinking about these ideas before beginning the investigation.

Investigation

SAFETY: Students should wear goggles during this investigation.

1. Divide the class into teams of two. In this investigation, students build electroscopes to measure the electric force produced by the static charge of different materials when those materials are rubbed with wool. Stand by the materials stations to explain how the materials will be used and the amount each team will receive. Students should go to the stations to collect the materials they will use at their desks.

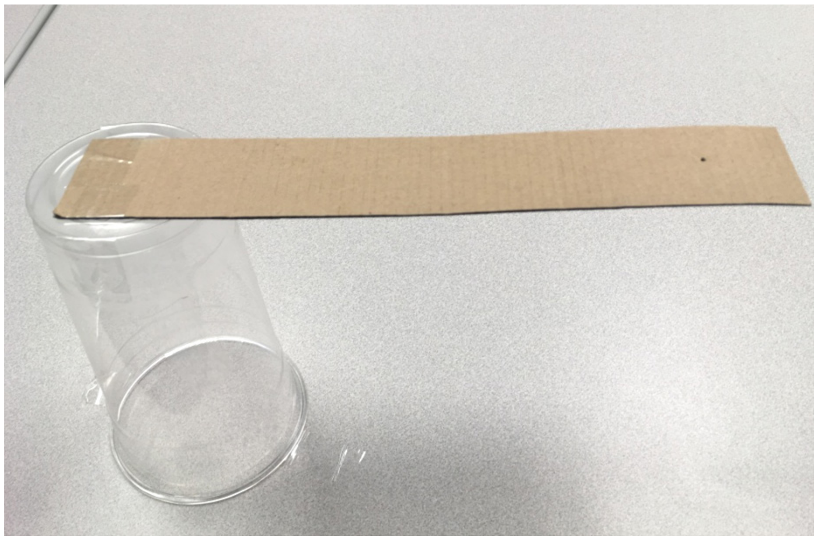
Pick-Up Station 1:

- cardboard strips 2"x 10" (pre-cut by teacher or cut by students) – 1 per team
- large plastic cups (24 oz) – 1 per team
- large paper clip – 1 per team
- scissors – 1 per team
- invisible tape – 1 per team
- rulers – 1 per team

Explain that each team will:

- ☐ **Create the electroscope stand:**
  1. Collect (or cut) one cardboard strip about 2" x 10" long.
  2. Open the paper clip until it has one long straight end and one hook end.
  3. Carefully make a hole in the cardboard strip by pushing the long end of the paper clip through the cardboard close to one end. Remove the paper clip and set it aside.

4. Turn the plastic cup upside down and tape it in place near the edge of a table or desk.
5. Tape the end of the cardboard strip without the hole to the bottom of the upturned cup so the majority of the strip hangs off the cup.



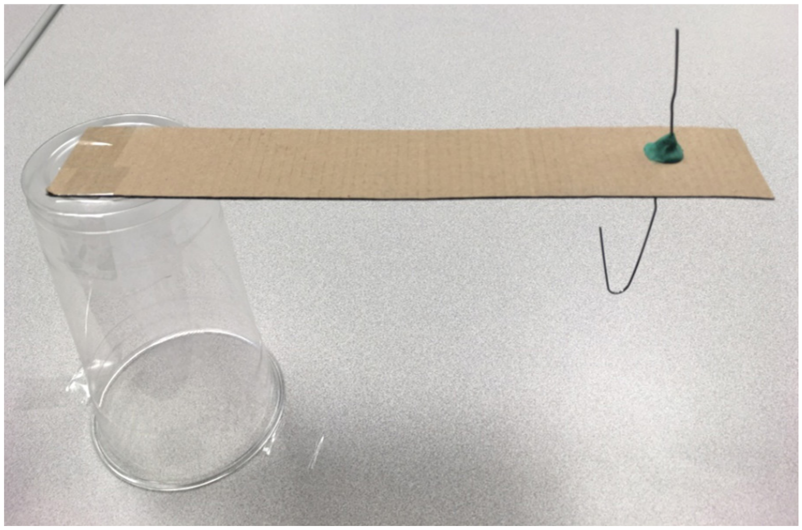
<u>Pick-Up Station 2</u>:

- non-drying clay – 1 small (pea-sized) piece per team

Explain that each student will:

- ☐ **Attach the paper clip to the cardboard strip:**

1. Carefully push the long end of the paper clip up through the hole in the cardboard strip, about 4-6 centimeters, so the paper clip hook hangs under the cardboard strip.
2. Make sure the paper clip is as straight as possible. Secure the paper clip to the cardboard with a small piece of clay.



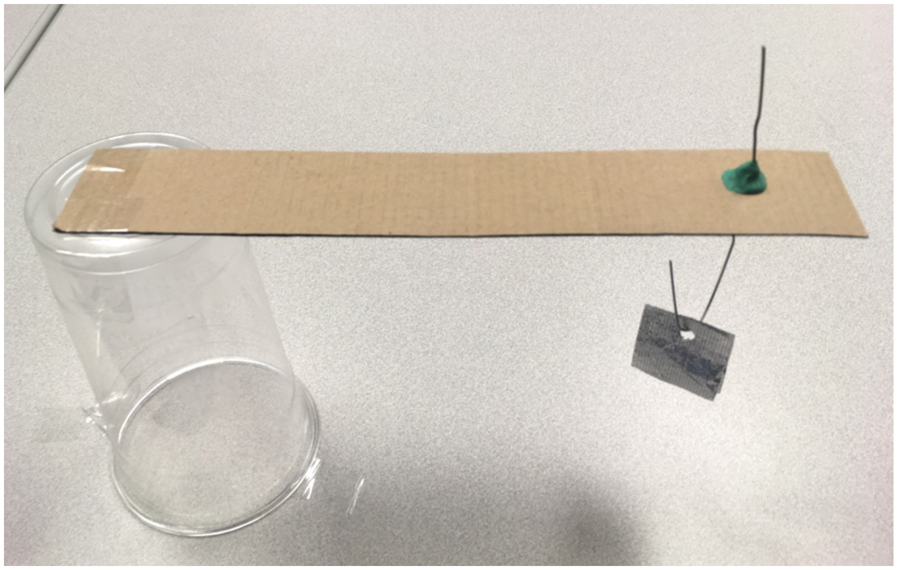
Pick-Up Station 3:

- aluminum foil – 1 sheet per team
- hole punches – shared

Explain that each student will:

- ☐ **Create the foil sheets for the electroscope:**
  1. Use scissors to cut two identical rectangles (about 4 cm x 3 cm or larger) out of the aluminum foil.
  2. Punch one hole in the same location in each foil sheet. The holes should be near the top, short ends of the sheets.
  3. Put the foil sheets onto the hook end of the paper clip. The two sheets of foil should lay flat and parallel to each other.

NOTE: To make the foil sheets identical in size and shape, students can fold their large foil sheet in half and then cut the rectangles out of it.



2. Students collect materials from the pick-up stations to set up their electroscopes. Circulate throughout the class to help troubleshoot or to ask questions and gauge student thinking as they assemble the electroscopes.

3. When teams have finished assembling the electroscopes, move on to the testing portion of the investigation. This is also a good stopping point if the entire investigation cannot be completed in a single class period.

NOTE: Electroscopes work best on cool, dry days. If the electroscopes seem non-responsive, wait until the weather cools and/or the humidity decreases. If the weather is too dry, however, the extra static charge from your own clothing might interfere with the results. Students can position the electroscopes so the foil sheets are hanging over the edge of a desk or table. This will minimize static charge from the table surface interacting with the foil.

Pick-Up Station 4:

- “Static Charge Investigation” – 1 per student (student reader)
- plastic rods (PVC) – 1 per team
- plastic cups (10 oz) – 1 per team
- wood dowels – 1 per team
- glass plates – 1 per team
- rulers – 1 per team
- wool cloth – 1 per team

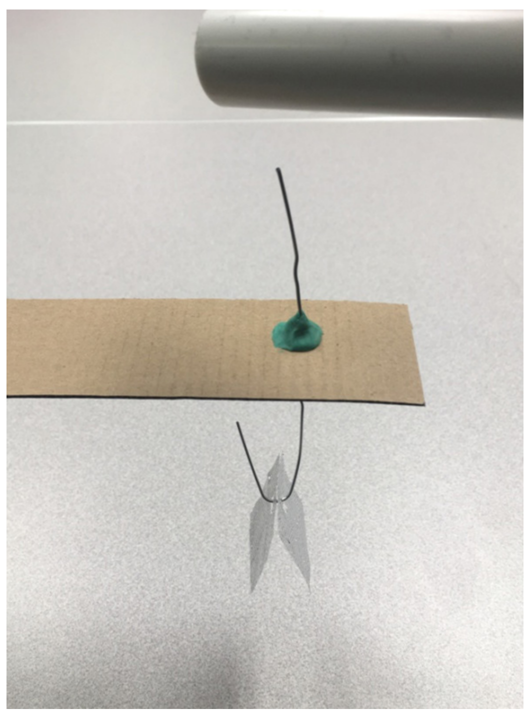
Explain that each student will:

- ☐ Use the “**Static Charge Investigation**” to explore the focus question: Look at the list of materials in Table 1 below. Will materials with a high static charge cause the foil sheets in your electroscope to move farther apart compared to materials with a low static charge? Use your electroscope and the test materials to explore the question.
- ☐ **Procedure**
  1. Rub the plastic PVC rod on the cloth for 10 seconds.
  2. Bring the charged rod near the paper clip on your electroscope.
  3. Measure the distance between the foil sheets on the electroscope with a ruler. Record the measurement in Table 1.
  4. Discharge the paper clip by touching it with your fingers. The foil sheets should return to their original position.
  5. Repeat Steps 1-4 with the plastic cup, wooden dowel, and glass plate.

Table 1: Comparing Static Charge of Different Materials when Rubbed with Cloth		
Materials	**Relative Static Charge When Rubbed with Cloth**	**Distance Between Foil Sheets (mm)**
plastic (PVC) rod	high	20
plastic (cup)	high	20
wood (dowel)	medium-low	3
glass (plate)	low	0

NOTE: Example data represent average results. Results will vary based on humidity and temperature levels in your classroom.

Photo shows the PVC rod being tested with the electroscope. The foil sheets have separated and are repelling each other.



4. Teams collect materials from the pick-up stations to test the materials with their electroscopes. Circulate throughout the class to help troubleshoot or to ask questions and gauge student thinking as they test the materials. The test materials will become negatively charged when rubbed with the cloth. The negative charge is transferred to the paper clip and foil, causing the foil sheets to repel each other since they both have a negative charge. When teams are finished collecting data, they can also test different materials and surfaces in the classroom, if time allows.

Wrap-Up:

1. Begin a dialogue with students to review how electrically charged materials exert forces on other materials without coming into contact with one another. For example:

- Ask one student how rubbing the different materials with the wool cloth caused static charge. [*Electrons can transfer when two different objects come into contact with one another. When you rub the wool against the different materials, they are brought into contact multiple times. This allows electrons to be pulled from the wool to the different materials.*]
- Ask another student what the role of the paper clip was in the electroscope. [*The paper clip is a conductor, so electrons can move through it easily.*]
- Ask the first student why the foil sheets on the electroscope moved apart during the tests. [*At rest, the foil pieces of the electroscope are neutral, which means they don't have a positive or negative charge. When the negatively charged materials were brought near the end of the paper clip, each foil strip attached to the paper clip acquired a negative charge, which caused them to repel each other.*]

2. Continue the dialogue with students, reviewing how static electricity results from a buildup of electric charge on a surface. For example:

- Ask one student why materials sometimes generate an electric charge. [*Electric charge occurs because of the atomic structure of different materials. All of matter is made up of atoms, which are made up of smaller protons, neutrons, and electrons. Protons and electrons are charged particles. If a substance has more protons than electrons, it has a positive charge. If it has more electrons than protons, it has a negative charge.*]
- Ask another student what causes electrons to move. [*The positive charge of protons pulls the negatively charged electrons toward the protons, and negatively charged electrons repel each other, pushing away.*]

Name: ____ Date: ______________

Static Charge Investigation

Focus question: Look at the list of materials in Table 1 below. Will materials with a high static charge cause the foil sheets in your electroscope to move farther apart compared to materials with a low static charge? Use your electroscope and the test materials to explore the question.

Procedure

1. Rub the plastic PVC rod on the cloth for 10 seconds.
2. Bring the charged rod near the paper clip on your electroscope.
3. Measure the distance between the foil sheets on the electroscope with a ruler. Record the measurement in Table 1.
4. Discharge the paper clip by touching it with your fingers. The foil sheets should return to their original position.
5. Repeat Steps 1-4 with the plastic cup, wooden dowel, and glass plate.

Table 1: Comparing Static Charge of Different Materials when Rubbed with Cloth

Materials	Relative Static Charge When Rubbed with Cloth	Distance Between Foil Sheets (mm)
Plastic (PVC) rod	high	
plastic (cup)	high	
wood (dowel)	medium-low	
glass (plate)	low	

Lesson 2: Magnets and Magnetic Fields

Objective: Students use iron filings to visualize the magnetic field interactions of permanent magnets and then test magnets of different sizes.

Materials:

Consumable

A. Goggles – 1 per student
B. “Magnetic Fields Investigation 1 and 2” – 1 per student (student reader)
C. Graduated cups (30 mL) – 1 per team
D. Poster paper – 1 per team
E. Small paper clips – 1 per team*
F. Plastic cups (10 oz)* – 1 per team

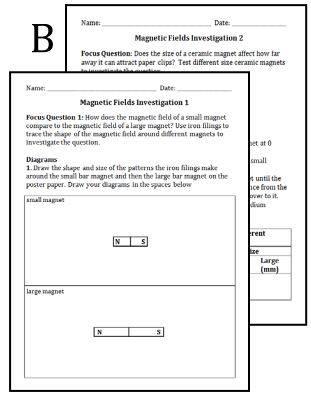
Non-Consumable

G. Small bar magnets (3 cm x 1 cm) – 2 per team
H. Medium bar magnets (2 cm x 1.5 cm) – 1 per team
I. Large bar magnets (4 cm x 2 cm) – 1 per team
J. Iron filings – shared
K. Magnets and Their Magnetic Fields Visual – (not shown)

Teacher Tool Kit

L. Invisible tape – 1 per team
M. Rulers – 1 per team

A

B


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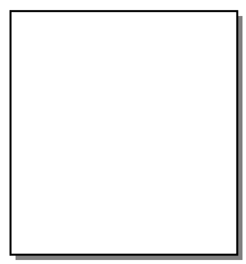
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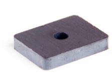

I

J

L

M


*These items are used again in Lesson 3.

NOTE: The size of the bar magnets you receive in your kit may vary slightly from the dimensions shown in this lesson.

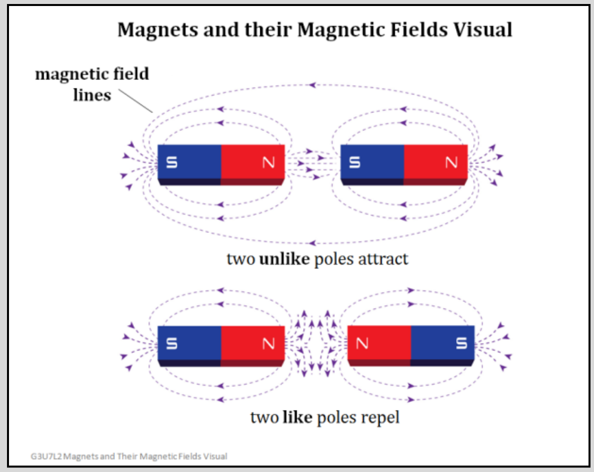
<u>Teacher Preparation</u>:

- Download the visuals from the KnowAtom Interactive website.
- There are two parts to this lesson: Magnetic Fields Investigations 1 and 2. Plan to organize the following pick-up stations for each investigation in the lesson. For example:
- **Magnetic Fields Investigation 1**
    - <u>Pick-Up Station 1</u>: student readers and small bar magnets
    - <u>Pick-Up Station 2</u>: iron filings, graduated cups (30 mL), plastic cups (10 oz), and invisible tape
- **Magnetic Fields Investigation 2**
    - <u>Pick-Up Station 1</u>: student readers, small bar magnets, medium bar magnets, and large bar magnets
    - <u>Pick-Up Station 2</u>: rulers and paper clips

<u>Student Reading Preparation</u>:

- Read Section 2 of the student reader together as a class before the Socratic dialogue and activity portion of the lesson. Section 2 reading applies to both Lesson 2 and Lesson 3. Model how to read closely for understanding. For example:
    - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
    - Use "why" and "how" questions to connect ideas in the reading to student experiences.

Block 2: Introduction to Magnetism



1. Display *Magnets and Their Magnetic Fields Visual*. Continue the dialogue from the last lesson, focusing on how magnetic forces follow similar rules to electric forces: opposites attract and likes repel.

- **Big Idea 5:** Coach students toward the idea that a **magnet** is any object that produces a magnetic field. A **magnetic field** is the area around a magnet that attracts or repels other magnets or magnetic materials such as iron. For example:
  - *Ask one student what happens to a magnet when it enters into another magnet's magnetic field. (A magnetic field applies a force to other magnets within it. This force can be a push or a pull.)*
  - *Ask another student how we can tell how large a magnet's magnetic field is. (Stronger magnets have a larger magnetic field, and a magnet's strength depends on its material. A magnet's magnetic field is invisible, but other magnets within it will be pushed away from or pulled toward the magnet.)*
  - *Ask the first student what makes a magnet attract another magnet. (All magnets have a north pole and a south pole. The north pole of one magnet always attracts the south pole of another. This is a pulling force.)*
  - *Ask another student what makes a magnet repel another magnet. (Two north poles will always repel each other. Two south poles will also repel each other. These are pushing forces.)*

- *Ask the first student what happens to non-magnetic objects that enter into a magnet's magnetic field. (These objects are not affected by magnets, so they won't be pushed or pulled.)*
- *Ask another student why magnetic fields make magnets useful. (A magnet can attract or repel other magnets without touching them as long as the other magnets are in its magnetic field.)*

Investigation 1: Magnetic Fields

SAFETY: Students should wear goggles during this investigation.

1. Divide the class into teams of two. In this investigation, teams use iron filings to observe the shape and patterns of magnetic field lines from bar magnets in different configurations. Stand by the materials stations to explain how the materials will be used and the amount each student will receive. Students should go to the stations to collect the materials they will use at their desks.

Pick-Up Station 1:

- "Magnetic Fields Investigation 1" – 1 per student (student reader)
- small bar magnets (3 cm x 1 cm) – 2 per team

Pick-Up Station 2:

- iron filings – 5-mL sample or less
- graduated cups (30 mL) – 1 per team
- plastic cups (10 oz) – 1 per team
- invisible tape – 1 roll per team

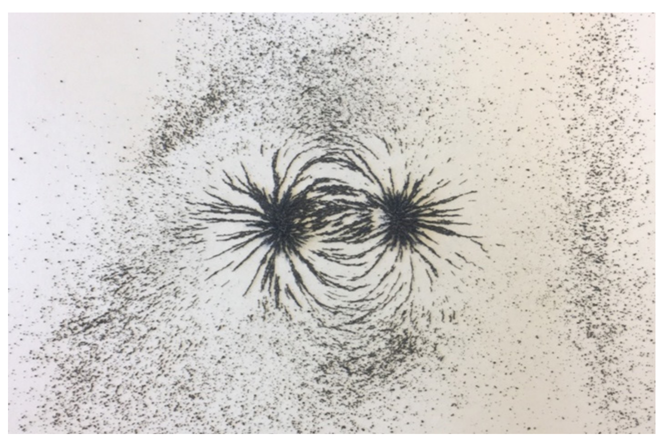
Explain that each team will:

- [ ] Use the "**Magnetic Fields Investigation 1**" to explore Focus Question 1: What does the magnetic field of a bar magnet look like? Investigate the question using iron filings to observe the shape of the magnetic field around one bar magnet.

- ☐ Set up the poster paper and magnets:
  1. Tape one small bar magnet to a flat surface (floor or large table).
  2. Lay the center of the poster paper on top of the magnet.
- ☐ Use the iron filings to observe the shape of the magnetic field around the small bar magnet:
  1. Collect a sample of iron filings in the 30-mL graduated cup. Slowly sprinkle the iron filings from about 8 centimeters (3 inches) above, onto the area of the paper on top of the magnet. Observe the magnetic field lines that appear as iron filings are attracted to the magnet under the paper.
  2. Once the magnetic field lines are clearly visible, diagram the shape and size of the patterns in the iron filings around the small bar magnet on the investigation sheet.
  3. Make a funnel with the poster paper to collect the iron filings in the plastic cup.

NOTE: If students sprinkle or pour too many iron filings onto the poster paper, it will be harder to see the magnetic field lines. If this occurs, students can collect the iron filings and repeat the process.

Photo shows the iron filings on top of the poster paper attracted to the magnetic field lines of the small bar magnet beneath it.



2. Teams collect materials from the pick-up stations to observe the iron filings with the small bar magnet. Circulate throughout the class to help troubleshoot or to ask questions and gauge student thinking as they use the magnets. When students have completed their diagrams, move onto the second part of the investigation using two small bar magnets.

Explain that each team will:

- Use "**Magnetic Fields Investigation 1**" sheet to explore Focus Question 2: How do the magnetic fields of attracting magnets compare to the magnetic fields of repelling magnets? Use iron filings to observe the shape of the magnetic fields around different sets of magnets to investigate the question.
- Set up the poster paper and magnets:
    1. Tape one small (3cm x 1 cm) bar magnet to a flat surface (floor or large table) and then tape a second small bar magnet 2.5 centimeters (1 inch) next to the first magnet so the opposing poles are facing each other (north-south).
    2. Lay the center of the poster paper on top of the magnets.
- Use the iron filings to observe the shape of the magnetic fields around the bar magnets:
    1. Collect a sample of iron filings in the 30-mL graduated cup. Slowly sprinkle the iron filings from about 8 centimeters (3 inches) above, onto the area of the paper on top of the magnets. Observe the magnetic field lines that appear as iron filings are attracted to the magnets under the paper.
    2. Once the magnetic field lines are clearly visible, diagram the patterns the iron filings make around the <u>attracting</u> magnets. Use the magnet outlines as a guide.
    3. Make a funnel with the poster paper to collect the iron filings in the plastic cup (10 oz).
    4. Repeat Steps 1-3, this time re-taping the bar magnets and orienting them so their like poles (north-north or south-south) are facing each other.

Photo shows the iron filings on top of the poster paper attracted to the magnetic field lines of two attracting small bar magnets under the poster paper.

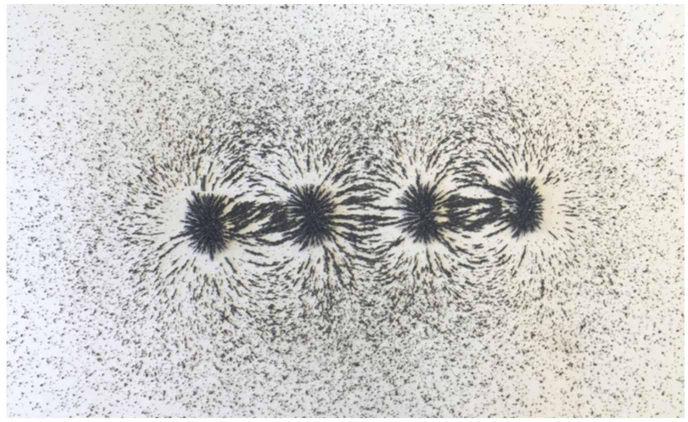
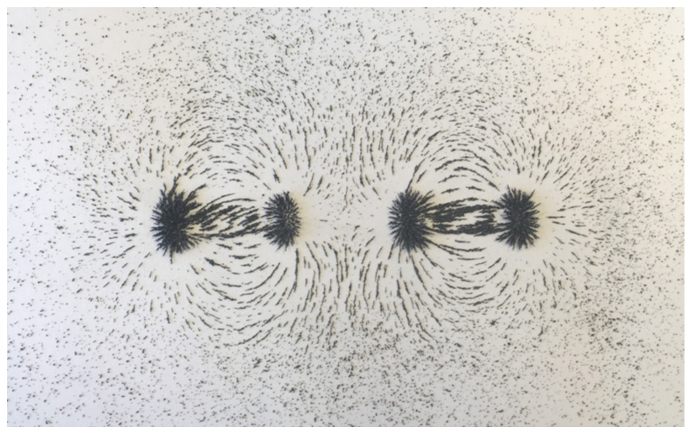


Photo shows the iron filings on top of the poster paper attracted to the magnetic field lines of two repelling small bar magnets under the poster paper.



3. Students use the materials to carry out the investigation. Circulate throughout the class to help troubleshoot or to ask questions and gauge student thinking as they use the magnets. Iron filing should be returned to the original container when the investigation is complete.

<u>Wrap-Up</u>:

1. Begin a dialogue with students to review the results of their investigation and their observations of magnetic fields. For example:

- Ask the class whether they were surprised by anything in the investigation. [*Answers will vary. For example, students may be surprised that the iron filings followed the magnet's magnetic* *field the way they did, allowing them to see its shape and size even though the magnetic field itself is invisible.*]

- Ask one student what causes the shape of a magnet's magnetic field. [*The magnetic field enters and exits from the magnet's poles, forming two circles around the length of the magnet.*]
- Ask one student how the investigation helped to answer the focus question: How do the magnetic fields of attracting magnets compare to the magnetic fields of repelling magnets? [*The investigation showed that when two magnets repelled each other, there were open spaces between the two magnets' magnetic fields. When two magnets attracted each other, magnetic field lines connected the two magnets.*]
- Ask another student how the investigation about magnets relates to the first lesson, which focused on static charge. [*Both magnetic forces and electric forces are attractive or repulsive, and both follow the same rules: opposites attract and likes repel.*]
- One at a time, provide multiple students with the chance to respond to this question, using their observations or background knowledge about attractive and repulsive forces to support their response.

<u>Investigation 2</u>: Magnetic Fields

SAFETY: Students should wear goggles during this investigation.

1. Divide the class into teams of two. In this investigation, teams test ceramic magnets of difference sizes to see how the size of the magnets affects how far away they can attract paper clips. Stand by the materials stations to explain how the materials will be used and the amount each student will receive. Students should go to the stations to collect the materials they will use at their desks.

<u>Pick-Up Station 1</u>:

- "Magnetic Fields Investigation 2" – 1 per student (student reader)
- small (3 cm x 1 cm) bar magnets – 1 per team
- medium (2 cm x 1.5 cm) bar magnets – 1 per team
- large (4 cm x 2 cm) bar magnets – 1 per team

<u>Pick-Up Station 2</u>:

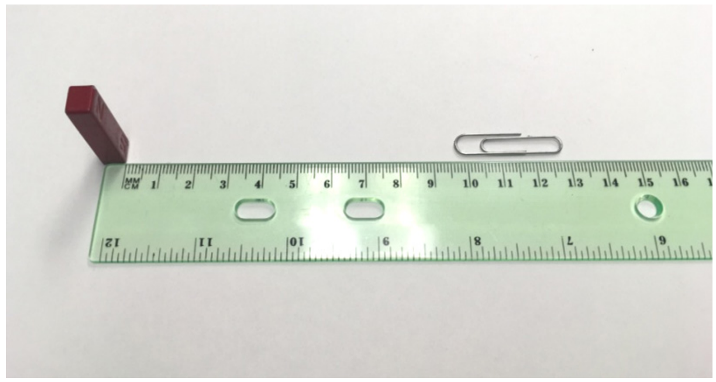
- rulers – 1 per team
- small paper clips – 1 per team

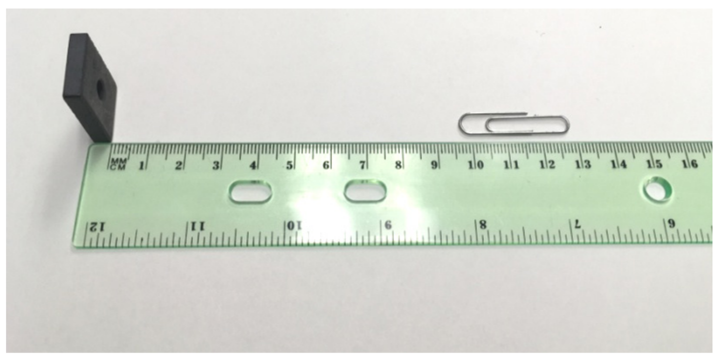
Explain that each team will:

- ☐ Use the "**Magnetic Fields Investigation 2**" to explore the focus question: Does the size of a ceramic magnet affect how far away it can attract paper clips? Test ceramic magnets of different sizes to investigate the question.
- ☐ Review the materials and procedure on the investigation sheet:
  1. Lay the ruler on a flat surface. Place the small magnet at 0 centimeters. The magnet should stand up on its short edge. Place the small paper clip at 10 centimeters.
  2. Move the magnet 0.5 centimeters closer to the small paper clip. Observe how the small paper clip responds to the magnet.

3. Repeat Step 2 until the magnet pulls the paper clip over to it. Record the distance the magnet was from the paper clip when it attracted the paper clip.
4. Repeat Steps 1-3 two more times, first with the medium magnet and then with the large magnet.

Photos show the small, medium, and large magnets being tested with the paper clip and ruler.





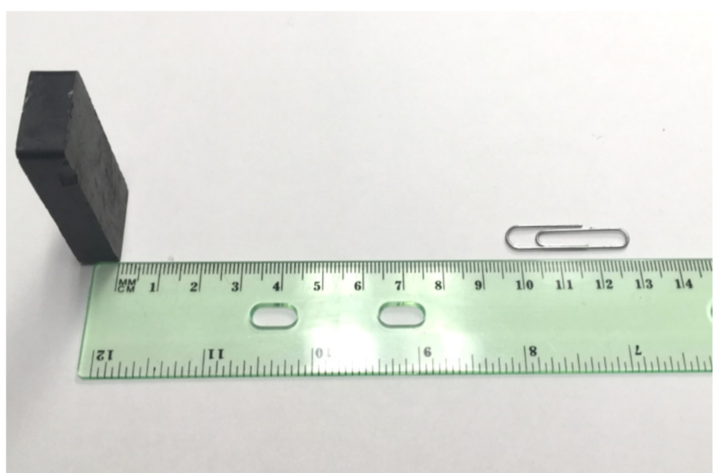


Table 1: Comparing Magnetic Fields of Ceramic Magnets of Different Sizes			
	Ceramic Magnet Size		
	Small	**Medium**	**Large**
How far away was the magnet from the paper clip when the magnet pulled it over? (cm)	0.5	1.5	4.5

NOTE: Example data represent one possible outcome.

2. Students collect materials from the pick-up stations to carry out the investigation. Circulate throughout the class to help troubleshoot or to ask questions and gauge student thinking as they test the magnets.

Wrap-Up:

1. Begin a dialogue with students to review how the force exerted by a magnet's magnetic field depends on the properties of the magnet, including its size. For example:

- Ask several teams to share their data from the investigation. Discuss any patterns the class observes in the data as different teams share. How do the results of the investigation support the claim that the large ceramic magnet has a stronger magnetic field compared to the smaller ceramic magnets? [*A magnet's magnetic field is the area around it that attracts or repels other magnets. We can conclude that the large magnet has the strongest magnetic field because it was able to attract the paper clip from the farthest distance.*]
- Ask teams to apply what they know about what makes magnets attract one another to explain how the poles of the

small, medium, and large magnets interacted with the poles of the paper clip. [*Because opposite poles attract, we can conclude that the opposite pole of the small, medium, and large magnets attracted the opposite pole of the paper clip.*]

2. Continue the dialogue with students, connecting the results from this investigation with the previous investigation. For example:

- Ask one student what was similar about this investigation, which compared the distance from a magnetic object a magnet had to be to exert a force on it, and the previous investigation, which explored magnetic fields. [*The magnetic field of the magnets is what is acting on the paper clip. Even though we can't see it, the first investigation provided evidence that it is there and it extends beyond the magnet itself. This investigation showed the effects of the magnetic field: the attractive pull it exerts on magnetic materials such as paper clips.*]
- One at a time, provide multiple students with the chance to respond to this question so that students are making connections between the two investigations. Redirect if misconceptions arise but allow students the chance to ask questions of and respond to one another.

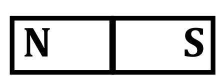
Name: ________________________________ Date: ________________

Magnetic Fields Investigation 1

Focus Question 1: What does the magnetic field of a bar magnet look like? Investigate the question using iron filings to observe the shape of the magnetic field around one bar magnet.

Diagram

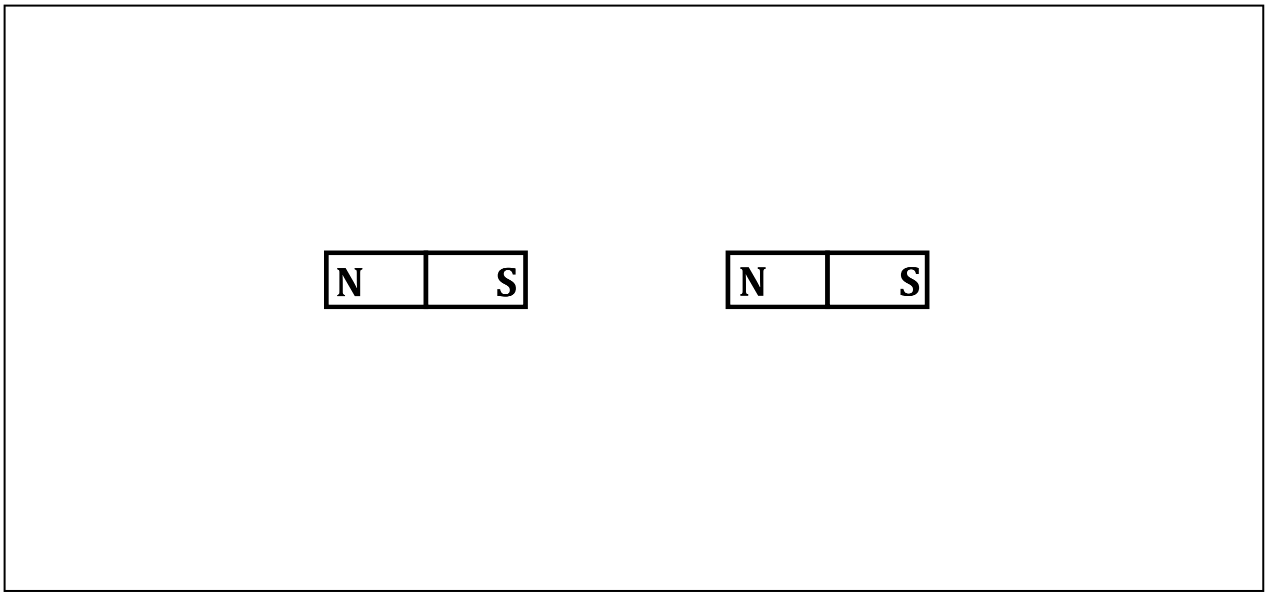
1. Observe the shape and size of the patterns the iron filings make around the small bar magnet on the poster paper. Draw a diagram of what you see in the space below, using the magnet outline as a guide.



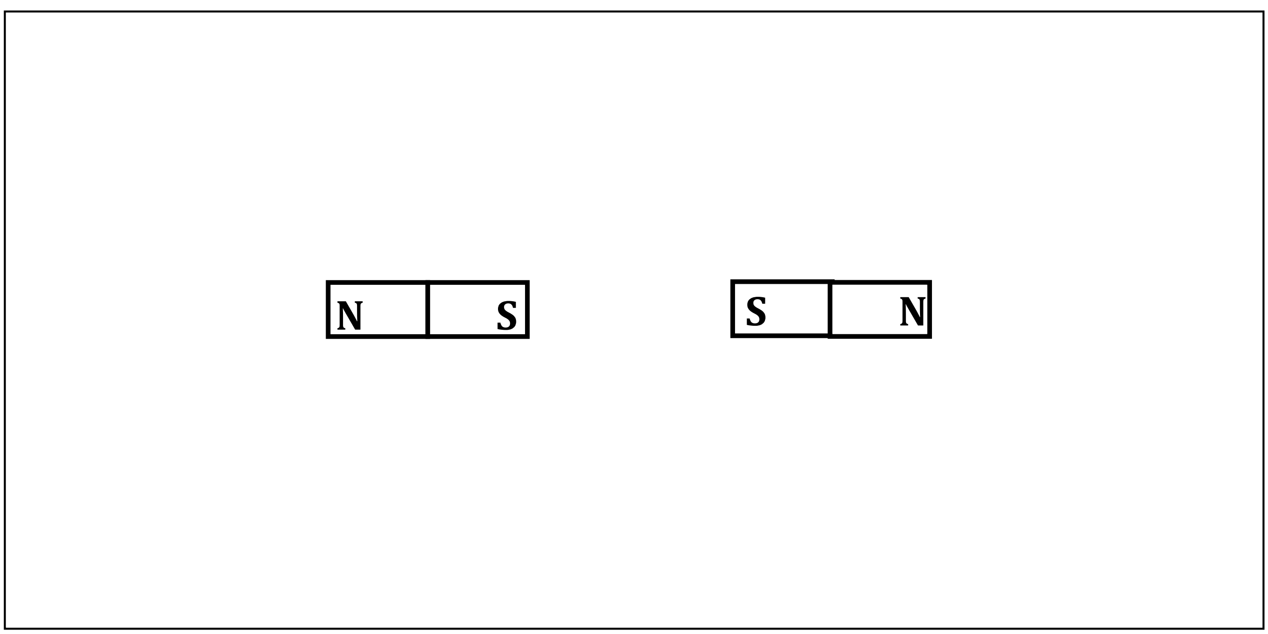
Focus Question 2: How do the magnetic fields of attracting magnets compare to the magnetic fields of repelling magnets? Use iron filings to observe the shape of the magnetic fields around different sets of magnets to investigate the question.

Diagrams

1. Draw the patterns the iron filings make around the <u>attracting</u> magnets in the space below. Use the magnet outlines as a guide.



2. Draw the patterns the iron filings make around the repelling magnets in the space below. Use the magnet outlines as a guide.



Name: ______________________________ Date: _______________

Magnetic Fields Investigation 2

Focus Question: Does the size of a ceramic magnet affect how far away it can attract paper clips? Test ceramic magnets of different sizes to investigate the question.

Materials

- 1 small bar magnet
- 1 medium bar magnet
- 1 large bar magnet
- 1 ruler
- 1 small paper clip

Procedure

1. Lay the ruler on a flat surface. Place the small magnet at 0 centimeters. The magnet should stand up on its short edge. Place the small paper clip at 10 centimeters.
2. Move the magnet 0.5 centimeters closer to the small paper clip. Observe how the small paper clip responds to the magnet.
3. Repeat Step 2 until the magnet pulls the paper clip over to it. Record the distance the magnet was from the paper clip when it attracted the paper clip.
4. Repeat Steps 1-3 two more times, first with the medium magnet and then with the large magnet.

Table 1: Comparing Magnetic Fields of Ceramic Magnets of Different Sizes			
	Ceramic Magnet Size		
	Small	**Medium**	**Large**
How far away was the magnet from the paper clip when the magnet pulled it over? (cm)			

Lesson 3: Engineering Pick-and-Place Devices

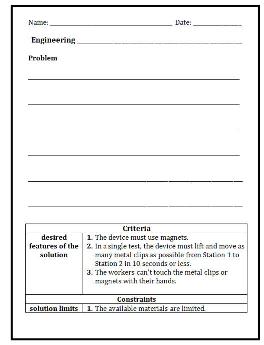
Objective: Students apply what they know about magnets and magnetic forces to design a device that can pick up and place metal paper clips for a metal factory.

Materials:

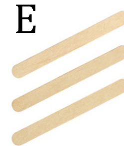
Consumable

A. Goggles – 1 per student
B. “Engineering” sheet
– 1 per student
(student reader)
C. Large paper clips*
– 15 per team
D. Plastic cups (10 oz)*
– 3 per team
E. Small craft sticks
– 10 per team
F. Large craft sticks
– 5 per team
G. Clothespins
– 2 per team
H. Dowels – 1 per team*
I. Paint stirrers
– 1 per team
J. Felt – 1 sheet per team
K. String – 1 meter per team
L. Small paper clips
– 5 per team
M. Factory Test Templates
– 1 per team

A

B

C

D

E

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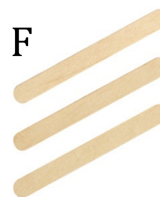
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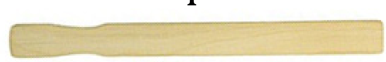
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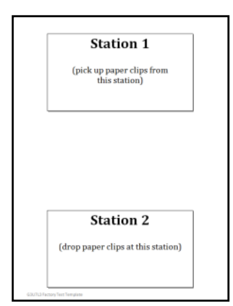


Non-Consumable

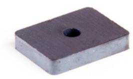
N. Clear plastic cylinders – 1 per team

N

*These items are reused from Lessons 1-2.

O. Small bar magnets (3 cm x 1 cm) – 2 per team
P. Medium bar magnets (2 cm x 1.5 cm) – 2 per team
Q. Bar magnets (7.5 cm x 1 cm) – 1 per team
R. Round magnets – 1 per team
S. Large bar magnets (4 cm x 2 cm) – 1 per team
T. Timers – 1 per team
U. Magnets in Engineering Visual – (not shown)
V. Engineering Scenario Visual – (not shown)

O


P


Q


R


S


T


Teacher Tool Kit
W. Scissors – 1 per student
X. Invisible tape – 1 per team

W


X


NOTE: The size of the bar magnets you receive in your kit may vary slightly from the dimensions shown in this lesson.

<u>Teacher Preparation</u>:

- Download the visuals from the KnowAtom Interactive website.
- Arrange several pick-up stations for students to collect materials to use at their desks during the lesson. For example:
  - <u>Pick-Up Station 1</u>: goggles, student readers, invisible tape, scissors, and timers
  - <u>Pick-Up Station 2</u>: large and small craft sticks, dowels, paint stirrers, and clothespins
  - <u>Pick-Up Station 3</u>: string, clear plastic cylinders, felt, and plastic cups
  - <u>Pick-Up Station 4</u>: large and small paper clips, magnets, and Factory Test Templates

Socratic Dialogue:

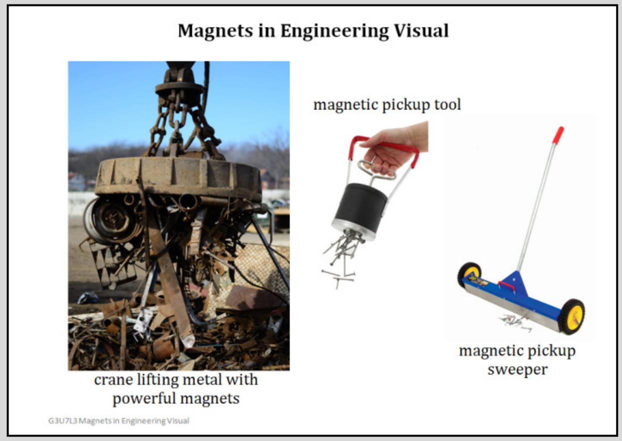
Block 3: Engineering with Magnets

1. Have a dialogue with students about how engineers use what they know about magnetic forces and magnetic fields to design technologies that solve specific problems.

- **Big Idea 6**: Coach students toward the idea that engineers who want to use magnets need to know about magnetic properties of materials and how magnets exert a force on other magnetic materials. For example:
    - *Ask one student to use evidence from their last investigation to describe how magnets can attract or repel magnetic objects. (A magnetic field applies either a pushing (repulsion) or a pulling (attractive) force to other magnets within it. In the second investigation in the last lesson, the ceramic magnets pulled paper clips toward them)*
    - *Ask another student what affected whether the paper clips were pulled toward the ceramic magnet. (The proximity of the magnet to the paper clip affect whether the paper clips were pulled toward the magnet. When the paper clips were outside of the magnet's magnetic field, they weren't affected by the magnet's magnetic field. The magnet had to move closer to the paper clip in order to attract it.)*
    - *Ask the first student what property of the magnet affected how far away the paper clips could be before they were affected by the magnet's magnetic field. (The size of the magnet affected how far away the paper clip could be before it was pulled on by the magnet. The large magnet had a larger magnetic field than the medium or the small magnets of the same material.)*

2. Display *Magnets in Engineering Visual*. Continue the dialogue with students, focusing on how magnets are used in many different applications because of their ability to exert a force on other magnetic materials without coming into contact with one another.

- **<u>Big Idea 7</u>:** Transition to the engineering investigation by coaching students toward the idea that engineers can use magnets when they design technologies that need to attract or repel objects without coming into contact with them. For example:



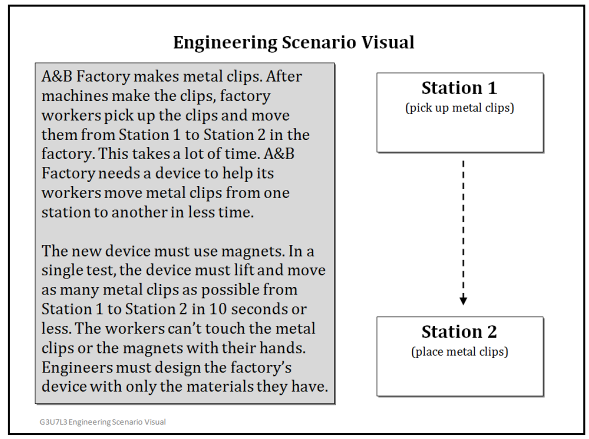
  - *Ask one student how magnets could be used to pick up objects from the ground. (Because magnets can attract other magnetic materials, they can be used to pull toward them other magnets or magnetic materials, such as those containing iron.)*
  - *Ask another student what engineers would need to think about when designing a device that can pick up objects. (Engineers would need to think about the kinds of materials their magnetic device would be able to pick up (only other magnets or magnetic materials). This is because non-magnetic objects aren't affected by a magnet's magnetic field. They would also need to think about what the device would do with the picked-up objects once it has pulled them toward it. Do they need to place them somewhere else? If so, how will their device separate the objects to place them in the new location?)*
  - *One at a time, provide multiple students with the chance to explore this question. There is no "right" answer. Students should explore the scientific concepts they will need to carry out their engineering investigation, as well as the practical questions they will need to address in their design.*

Engineering – Magnetic Pick-and-Place Devices

SAFETY: Students should wear goggles during this activity.

Engineering Scenario

Display the *Engineering Scenario Visual*. As a class, read and discuss the engineering scenario on the visual. (The visual can also be printed for each student if needed.): "A&B Factory makes metal clips. After machines make the clips, factory workers pick up the clips and move them from Station 1 to Station 2 in the factory. This takes a lot of time. A&B Factory needs a device to help its workers move metal clips from one station to another in less time. The new device must use magnets. In a single test, the device must lift and move as many metal clips as possible from Station 1 to Station 2 in 10 seconds or less. The workers can't touch the metal clips or the magnets with their hands. Engineers must design the factory's device with only the materials they have."



Problem

Divide the class into teams of two. Students collect their student readers and turn to the "Engineering" sheet. As a class, discuss the scenario to come up with a brief description that accurately summarizes the primary need/problem. If needed, first work with the class to summarize the problem and then have students write the problem summary on their engineering sheets. For example:

- **Problem**: *A&B Factory needs a magnetic device to help its workers move metal clips from one station to another in less time.*

Once the problem is summarized, move on with the class to describe the criteria (the desired features or requirements of the solution) and solution constraints (ways the solution is limited). Students review the criteria and constraints of the problem listed on their engineering sheets in order to understand the scope of the problem, which will help them better evaluate the effectiveness of their prototype solutions later on. The criteria and constraints are taken directly from the engineering scenario story. Briefly walk through the criteria and constraints outlined on the engineering sheet with the class.

<u>Criteria</u>:

1. *The device must use magnets.*
2. *In a single test, the device must lift and move as many metal clips as possible from Station 1 to Station 2 in 10 seconds or less.*
3. *The workers can't touch the metal clips or magnets with their hands.*

<u>Constraints</u>:

1. *The available materials are limited.*

Once the engineering problem, criteria, and constraints are established, students collaborate within their team or as a class to create a title for the engineering challenge that is relevant to the problem. For this engineering challenge, a relevant title is "Engineering Magnetic Pick-and-Place Devices," but other titles can be used as well.

NOTE: When students are finished summarizing the problem, use the *<u>Who is an Engineer?</u>* poster in place of the *<u>Engineering Scenario Visual</u>* to help guide them through the engineering process.

Research
For research, students use their student readers or prior knowledge from discussions to answer the following research questions related to the problem on their engineering sheets:

1. What is a magnet? [*A magnet is an object that produces a magnetic field that attracts or repels other magnets and magnetic materials such as iron*.]
2. How could magnets be useful in the device for the factory? [*Magnets could be useful because they can attract other magnets or magnetic materials without coming into contact with them.*]

Survey Available Materials
As a class, survey the available materials. The purpose of the materials survey is for students to observe the quantity and properties of the available materials. As students examine the materials, they should be thinking about the problem and how the properties of the materials could be used to help solve the problem. Stand by the pick-up stations and point out the materials each student will use to create their prototype solution.

<u>Prototype Materials (per team)</u>:

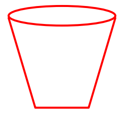
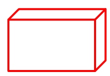
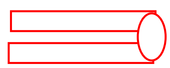
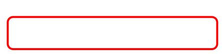
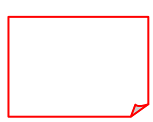
- 10 small craft sticks
- 5 small paper clips
- 5 large craft sticks
- 3 plastic cups
- 2 bar small magnets (3 cm x 1 cm)
- 2 bar medium magnets (2 cm x 1.5 cm)
- 2 clothespins
- 1 clear plastic cylinder
- 1 dowel
- 1 paint stirrer
- 1 sheet of felt
- 1 length of string (3 feet/1 meter)

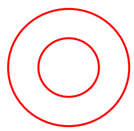
- 1 bar magnet (7.5 cm x 1 cm)
- 1 large bar magnet (4 cm x 2 cm)
- 1 round magnet

<u>Tools and Test Materials</u>:
- invisible tape – shared
- timers – 1 per team
- scissors – 1 per student
- Factory Test Template – 1 per team
- large paper clips (for testing) – 15 per team

Students record the missing information for each material in the Materials Survey Chart on their engineering sheets. Tools and test materials are not included in the materials survey chart. Students can collect a sample of each material or look at the materials at the pick-up stations to help them record the following information on their charts:
- a sketch of each material
- properties of each material (e.g., physical properties such as texture (smooth, rough, fuzzy), flexibility (rigid or bendable/flexible), shape, length or any other useful characteristics that you notice)

Materials Survey Chart				
Name	**Quantity**	**Sketch**	**Made From**	**Properties**
small craft sticks	10		wood	narrow, smooth, and hard
small paper clips	5		metal	flexible and thin

large craft sticks	5		wood	wide, smooth, and hard
cups	3		plastic	flexible and smooth
bar magnet (3 cm x 1 cm)	2		metal	smooth, narrow, and magnetic
bar magnet (2 cm x 1.5 cm)	2		metal	smooth, wide, and magnetic
clothespins	2		wood and metal	narrow and rigid
cylinder	1		plastic	long, rigid, and hollow
dowel	1		wood	long and rigid
paint stirrer	1		wood	long and flat
felt	1 sheet		nylon	thin and soft

string	1 meter		cotton	long and thin
bar magnet (7.5 cm x 1 cm)	1		metal	smooth, long, narrow, and magnetic
bar magnet (4 cm x 2 cm)	1		metal	smooth, wide, and magnetic
round magnet	1		metal	smooth and magnetic

Possible Solutions
At this point in the challenge, students use what they know about the criteria and constraints of the problem, as well as their research, available materials, and what they know about magnets, to work with their team to come up with at least two possible solutions to the problem. This step of the process might be challenging for some students, but it's an important planning strategy because it allows students to generate different types of solutions, share those solutions with their peers, and then select the solution that would be the most effective to build and test. The possible solutions should focus on ideas that allow for the effective picking up, moving, and placing of large metal paper clips from one area to another on the Factory Test Template.

Since students will not be testing their devices in a real factory, briefly show the class one of the Factory Test Templates. The test templates have areas marked "Station 1" and "Station 2." Point out that their prototype devices will need to pick up metal paper clips from Station 1 and move them to Station 2. The following are two possible solutions with varying levels of detail that your students may come up with:

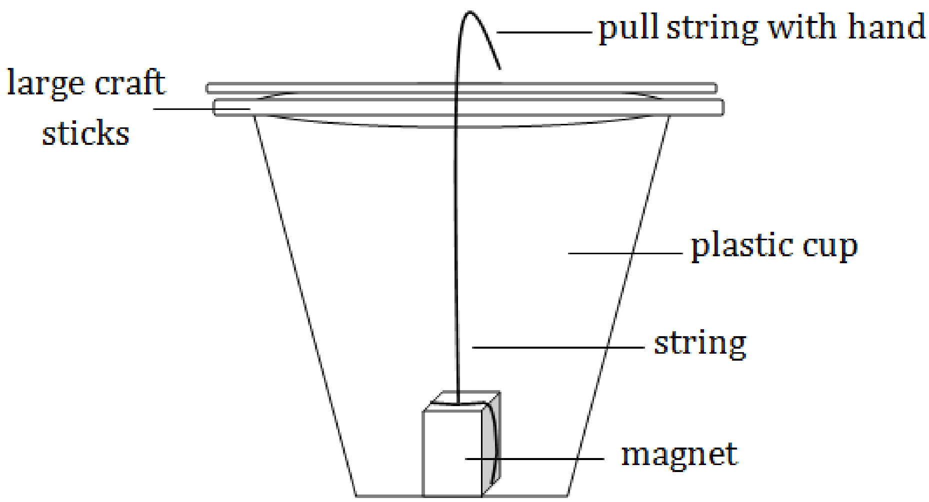
- Design a magnetic claw that picks up metal paper clips from Station 1 and shakes them loose onto Station 2.
- Design a device that raises and lowers a magnet to pick up and drop metal paper clips from Station 1 to Station 2.

Circulate throughout the class as teams come up with possible solutions. Students share their ideas with you and with each other. Students will sometimes come up with imaginative design ideas that may not be realistic given the available materials. Ask questions to help students compare their possible solutions and to determine which solution could be accomplished in the classroom. Teams may find that a combination of their possible solutions may work best and change their ideas accordingly. When teams are relatively confident with the possible solutions, they can independently choose which of their ideas would have the greatest likelihood of success as their solution before proceeding to the next step in the process. Variation in teams' possible solutions is expected and encouraged.

Diagram and Build Prototype

Students draw a scientific diagram of their prototype pick-and-place devices. All diagrams should be titled and include labels of materials used. Teams follow their prototype diagram when building. As teams are ready, they should check in with the teacher to review their prototype diagram before accessing materials to build. Are student diagrams complete? Diagrams should be titled and materials labeled. Can you understand student diagrams? Could you follow it to build the prototype? If not, clarify expectations. Students make corrections or any modifications and then return to the teacher for the go-ahead. When ready, teams collect the materials they need and then build their prototype based on their diagram.

Prototype Device 1 Diagram



NOTE: Teams are not required to use all of the available materials, but they can if needed or desired. Students should not cut the clear plastic cylinders because they are a durable item. There are many ways to build a functional magnetic device that picks and places paper clips from one place to another. If you observe that students aren't following their scientific diagram during the building process, require that they modify the drawing or prototype accordingly.

Test

Teams test their prototypes on their Factory Test Templates. Teams use the test procedure on their engineering sheets as a guide for carrying out the proper testing method. Briefly go over the test procedure with the class to ensure they are familiar with how to test their prototypes if needed.

<u>Test Procedure</u>:

1. Set up the Factory Test Template with 15 large paper clips.
2. Use your prototype device to pick up large paper clips in the area marked "Station 1" on the test template.

3. Move the paper clips over to the area marked “Station 2” on the template.
4. Release the paper clips from your device onto the “Station 2” area. Record how long it took to pick and place the paper clips.
5. Return the paper clips to Station 1 and repeat Steps 1-4 with Prototype 2 and Prototype 3.

Data

Students record data for each prototype in Table 1. Students record how long it took to move the paper clips from Station 1 to Station 2 and how many paper clips their prototype was able to pick up during the test. It is common for teams to build their first prototype in a way that allows it to pick up paper clips easily but not release them.

Table 1: Comparing Prototype Pick-and-Place Devices

	Time to pick up and place paper clips (seconds)	How many paper clips did it pick up and place?
Prototype 1	15	10
Prototype 2	16	12
Prototype 3	8	13

NOTE: Example data represent one possible outcome. Student data will vary throughout the class, depending on design.

Refine or Replicate

Students use what they learn from testing their first prototype to make improvements when creating Prototype 2. Students should go back to their original prototype diagram and make modifications to represent their second prototype before building and testing it. Students repeat this process for Prototype 3.

Students describe their results from the engineering challenge in the "Refine (improve) or Replicate (copy)" (conclusion) section of their investigation sheets. Students should be prepared to:

- Identify which prototype best solved the problem.
- Support the effectiveness of the prototype with key data (evidence) from Table 1.
- Recommend if one of the prototype solutions should be further improved or replicated for A&B Factory to use.

Refine or Replicate

Use your test data to explain which prototype solution best solved the problem (and why) and if you would refine or replicate any of your designs based on your data.

Our data show that Prototype # 3 **best solved A&B Factory's problem of moving metal clips from one station to another in less time because**

it picked up, moved, and dropped the most paper clips in the least time. It picked up, moved, and dropped 13 paper clips in 8 seconds. Our prototype used three magnets to lift and drop paper clips from Station 1 to Station 2.

____

____

____

Based on our data, we recommend engineers should

_____________replicate_______________ Prototype # _______3________

(refine or replicate)

for A&B Factory to solve their problem.

<u>Wrap-Up</u>:

1. Begin a dialogue with students to review their prototype solutions, asking them to explain how any modifications positively or negatively affected the prototype's ability to pick up and carry paper clips in 10 seconds or less. For example:

- Ask one student why they used engineering in the investigation instead of an experiment. [*There was a problem that needed to be solved. The problem was that it was taking workers at A&B Factory too long to move metal clips from one station to another.*]
- Ask another student whether they would recommend that either of their prototypes be refined (changed more) or replicated (kept as is and copied). Students should include data from their testing to support their explanation. [*Answers will vary depending on the specific design of each team, but all answers should connect back to the problem, and explain why*

they would recommend either refining or replicating their prototype. If none of their prototypes was able to pick up and carry paper clips in 10 seconds or less, students should recommend refining their prototypes more. If one of their prototypes was able to meet the criteria of the problem, students may recommend replicating their prototype.]

- Ask the first student to present their decision about whether to refine or replicate one of their prototypes, including data from their testing to support their decision. [*Answers will vary depending on the specific design of each team and their data.*]
- One at a time, ask students to describe any challenges they faced in designing and/or testing their prototype, and how they overcame those challenges.

2. Continue the dialogue with students, reviewing how students applied what they know about magnets to design their prototypes. For example:

- Ask one student how their prototype used magnets to help them solve the problem. [*Magnets were able to attract the paper clips because paper clips have iron in them, which is a magnetic material.*]
- Ask another student what challenges they faced in their design and how they overcame those challenges. [*Answers will vary depending on design. For example, some students may have struggled with how to release the paperclips at the second station. Provide multiple teams with the chance to explain how they addressed these challenges.*]
- One at a time, provide multiple students with the chance to respond to this question as students communicate about their prototype and how they developed it.

Name: ______________________________________ Date: _______________

Engineering ____

Problem

____

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Criteria	
desired features of the solution	**1.** The device must use magnets. **2.** In a single test, the device must lift and move as many metal clips as possible from Station 1 to Station 2 in 10 seconds or less. **3.** The workers can't touch the metal clips or magnets with their hands.
Constraints	
solution limits	**1.** The available materials are limited.

Research

1. What is a magnet?

2. How could magnets be useful in the device for the factory?

Survey Available Materials

Complete the materials survey chart below.

- Draw a simple sketch of each material.
- Record a description of what each material is made from.
- List 1-2 properties of each material. (Examples include physical properties such as thickness, flexibility, shape, relative weight, or any other physical characteristics that you notice.)

Materials Survey Chart				
Name	**Quantity**	**Sketch**	**Made From**	**Properties**
small craft sticks	10			
small paper clips	5			
large craft sticks	5			
cups	3			
bar magnet (3 cm x 1 cm)	2			
bar magnet (2 cm x 1.5 cm)	2			

clothespins	2			
cylinder	1			
dowel	1			
paint stirrer	1			
felt	1 sheet			
string	1 meter			
bar magnet (7.5 cm x 1 cm)	1			
bar magnet (4 cm x 2 cm)	1			
round magnet	1			

Possible Solutions

Use what you know about the problem and your research to list two possible solutions to the problem, given the available materials and what you know about magnets.

1. ____

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____

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2. ____

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____

Diagram and Build Prototype

Draw a diagram of your chosen prototype in the space on the next page. Label each material used in your prototype. Title the diagram.

Test Procedure

1. Set up the Factory Test Template with 15 large paper clips.
2. Use your prototype device to pick up large paper clips in the area marked “Station 1” on the test template.
3. Move the paper clips over to the area marked “Station 2” on the template.
4. Release the paper clips from your device onto the “Station 2” area. Record how long it took to pick and place the paper clips.
5. Return the paper clips to Station 1 and repeat Steps 1-4 with Prototype 2 and Prototype 3.

Data

Record your test data in Table 1 on the next page.

Table 1: Comparing Prototype Pick-and-Place Devices		
	Time to pick up and place paper clips (seconds)	**How many paper clips did it pick up and move?**
Prototype 1		
Prototype 2		
Prototype 3		

Refine or Replicate

Use your test data to explain which prototype solution best solved the problem (and why) and if you would refine or replicate any of your designs based on your data.

Our data show that Prototype # ______________________________ best solved A&B Factory's problem of moving metal clips from one station to another in less time because

____

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Based on our data, we recommend engineers should

__________________________ Prototype # ____________
(refine or replicate)

for A&B Factory to solve their problem.

Name: ______________________________________ Date: ______________

Unit 7: Magnetism and Electricity
Vocabulary Check

Part I: For questions 1-5, circle the best answer.

1. To __________________ means to push apart.

A. attract
B. conduct
C. repel
D. insulate

2. A(n)________________________________ is a material that electrons cannot pass through easily.

A. permanent magnet
B. electrical conductor
C. temporary magnet
D. electrical insulator

3. The area around a magnet that attracts or repels other magnets and magnetic materials such as iron is called a(n) ________________________.

A. magnetic field
B. electric insulator
C. static charge
D. electric conductor

4. _____________________ is the buildup of electric charge in an object.

A. Magnetism
B. Electric insulation
C. Static charge
D. Electric conduction

5. An object that stays magnetized without electricity is called a(n) ___________________________.

A. permanent magnet
B. south pole
C. temporary magnet
D. north pole

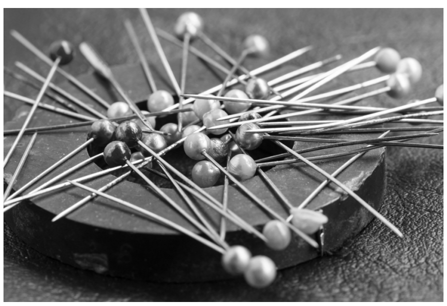
Name: ________________________________ Date: ______________

Unit 7: Magnetism and Electricity

Concept Check

Part I: For questions 1-2, circle the best answer.

1. The picture below shows a magnetic pin cushion. If you turn the pin cushion upside down, the pins won't fall off. But you can pick a pin up when you need to use it.



What causes the pins to stay on the magnetic pin cushion and not fall off?

A. The pins are glued to the pin cushion.
B. The pins have a positive electric charge and the pin cushion has a negative electric charge.
C. The pins are repelled by the pin cushion.
D. The pins are attracted to the pin cushion.

2. Elise rubs two balloons on her head and places them on a nearby wall. The balloons stay on the wall for about two minutes.

Why do the balloons stay on the wall?

A. Static charge causes the balloons to be repelled from the wall.
B. Static charge causes the balloons to be attracted to the wall.
C. Static charge causes the balloons to become magnets.
D. Magnetism causes the balloons to be attracted to the wall.

Part II: For questions 3-4, follow the instructions to answer each part of the question.

3. A Van de Graaff generator is a device that creates static charge. In it, a rubber band rubs across a piece of felt. As the rubber band moves across the felt, the felt's electrons move to the rubber band. The rubber band then sends the electrons up to a metal ball on top.

3a. Why is it important for the rubber band to rub against the felt?

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3b. Look at the picture above. Why does the boy's hair stand straight up when his hand is on the metal ball of the Van de Graaff generator?

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4. Juan walks across a rug. He then touches a metal doorknob. He gets a small electric shock.

4a. Juan is curious. He wants to know why he got a small electric shock. He researches his question. He reads that he gained a negative static charge when he walked across the rug. How could Juan get a negative charge?

4b. What caused the electric shock when Juan touched the metal doorknob?

4c. Juan wonders whether he would get an electric shock if he walks across other surfaces. He decides to test his question. He walks across a wooden floor and then touches a metal doorknob. He then walks across a tiled floor before touching a metal doorknob. He doesn't get a shock.

What is the most likely explanation for why he got an electric shock only when he walked across the rug?

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<u>**Unit 7: Appendix 1**</u>
Answer Keys

Vocabulary Check

Part I

1. C. repel [To repel means to push apart. To attract means to pull together. To conduct means to allow something (such as electrons in the case of electrical conductors) to flow through easily. To insulate means to keep something (such as electrons in the case of electrical insulators) from flowing through easily.]
2. D. electrical insulator [An electrical insulator is a material that electrons cannot pass through easily. An electrical conductor is a material that electrons can easily pass through. A permanent magnet is an object that stays magnetized without electricity. A temporary magnet is an object that acts like a permanent magnet when it is within a strong magnetic field.]
3. A. magnetic field [The area around a magnet that attracts or repels other magnets and magnetic materials such as iron is called a magnetic field. Static charge is the buildup of electric charge in an object. An electrical insulator is a material that electrons cannot pass through easily. An electrical conductor is a material that electrons can easily pass through.]
4. C. Static charge [Static charge is the buildup of electric charge in an object. Magnetism is the phenomena where some objects produce a magnetic field that can attract or repel other magnets or magnetic materials. Electrical conduction is the ease with which electrons can flow, while electrical insulation blocks electrons from flowing easily.]
5. A. permanent magnet [An object that stays magnetized without electricity is called a permanent magnet. A temporary magnet is an object that acts like a permanent magnet when it is within a strong magnetic field. All magnets have a north pole and a south pole. The north pole of one magnet always attracts the south pole of another. This is a pulling force. Two north poles and two south poles will always repel each other. These are pushing forces.]

Concept Check

Part I

1. D. The pins are attracted to the pin cushion. [The pins stay on the magnetic pin cushion and don't fall off even when the pin cushion is turned upside down because the pins are attracted to the magnetic pin cushion. To attract means to pull together. This is because the pins are made of a magnetic material that is affected by magnetic forces. If the pins were repelled by the magnetic pin cushion, they would be pushed away and wouldn't stay on it. It isn't true that the pins are glued to the pin cushion because it's possible to pick the pins up to use them. It also isn't true that the pins have a positive electric charge and the pin cushion has a negative electric charge. The force that pulls the pins and pin cushion together is magnetic, not electric.]
2. B. Static charge causes the balloons to be attracted to the wall. [If Elise rubs two balloons on her head and places them on a nearby wall, and the balloons stay on the wall for about two minutes, it is because static charge causes the balloons to be attracted to the wall. When Elise rubs the balloons on her head, electrons move from her head to the balloons. This gives the balloons a negative charge. Because opposite charges attract each other, the balloons are attracted to the positive charge of the wall, and it is this attractive pull that keeps the balloons on the wall.]

Part II

3. This question assesses how well students understand how electrons are transferred when two objects come into contact with one another, resulting in static charge.

3a. [The answer should explain that the rubber bands need to rub against the felt because the electrons can only transfer from the felt to the rubber band when the two materials come into contact with one another.]

3b. [The answer should explain that the boy's hair stands straight up because the electrons that moved from the felt to the rubber band and up to the metal ball. When the boy touches the metal ball, the electrons transfer to him. Because electrons have a negative charge, they repel one another. Each hair strand has electrons that are repelling each other.]

4. This question continues to assess student understanding of static charge, presenting a different scenario that causes static charge—walking across a rug.

4a. [Juan reads that he gained a negative static charge when he walked across the rug. This negative charge came from the contact between his feet and the rug. Electrons transferred from the rug to Juan. We know this because electrons have a negative charge, so if Juan gained a negative charge, it has to be because electrons transferred to him.]

4b. [Juan got an electric shock when he touched the metal doorknob because the electrons in his body were attracted to the positively charged doorknob. The shock was a result of electrons moving from Juan to the doorknob.]

4c. [The most likely explanation for why Juan only got an electric shock when he walked across a rug but not a wooden or a tiled floor is that those materials don't transfer electrons as easily. As a result, Juan wouldn't have built up a negative charge walking across them.]

Student Reader Answer Key

The section review questions at the end of each section in the reader are designed to use Common Core ELA standards to advance student comprehension of the reader. Students can answer these questions independently or they can be discussed as a class before the Socratic dialogue portion of the lesson.

Section 1 Reading Comprehension Questions

1. [An object becomes negatively charged when electrons transfer into it from another object, resulting in more negative charges (electrons) than positive charges (protons).]
2. [When we see a flash of lightning, we're actually seeing the electrons moving from the storm cloud to the ground or to other storm clouds. This is because the electrons in a storm cloud are attracted to the positively charged ground or the positive charge of the top of another storm cloud.]
3. [An object that has a positive charge moves toward an object that has a negative charge because opposite charges attract each other, which means they pull toward one another. This pulling force causes them to move toward each other.]
4. [When two negatively charged objects are close to each other, they repel each other. This means they push each other away.]
5. [The main idea of this section is that objects can become positively or negatively charged and can exert a force on other charged objects without coming into contact with them. This main idea is supported with different examples of static charge, including lightning and balloons that stick to walls.]

Section 2 Reading Comprehension Questions

1. [The north pole of one magnet is attracted to the south pole of another magnet because opposite poles attract. To attract means to pull together.]
2. [When two south poles or two north poles come near each other, they will repel one another because like poles repel. To repel means to push away.]
3. [A magnet will act on another magnet when the other magnet is within the first magnet's magnetic field.]

4. [The main idea of Section 2 is to describe the basic properties of magnetic materials and explain how magnets can exert a force on other magnetic materials without coming into contact with them. This main idea is supported with details about magnetic fields and examples of different kinds of magnets.]
5. [Section 1 connects to Section 2 because both focus on forces between objects that aren't in contact with one another. Section 1 explores electric forces and Section 2 explores magnetic forces.]

Unit 7: Appendix 2
Common Core Connections

The following Common Core standards are covered in this unit. Questions for the *Reading Informational Texts* standards provide an example of a question that links to a specific ELA standard. Additional questions are included in the section reviews. These types of questions can also be used with other texts. Other ELA standards are covered as students work through the reading, class dialogue, and hands-on portion of the lessons.

ELA Standards	Applying ELA Connections to the Student Reader
Writing	
W.3.4. With guidance and support from adults, produce writing in which the development and organization are appropriate to task and purpose.	• In Lesson 3, students continue to develop their ability to write in a clear and concise way as they are guided through an engineering lab in which they write out different parts of the engineering process.
Reading Informational Text	
RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers.	• Section 1 discusses lightning. Why is lightning used as an example in this section? [*Lightning is caused by static charge, which is the buildup of electric charge in an object. This section explores static charge, which is why lightning is used as an example.*] • Section 2 begins with a story about the world's strongest magnet. According to the text, why are engineers able to design different materials with the help of the magnet? [*They are able to because matter acts differently inside a powerful magnetic field.*]
RI.3.2. Determine the main idea of a text; recount the key details and explain how they support the main idea.	• What is the main idea of Section 2: Magnetic Forces? [*The main idea of this section is magnets exert a force on certain objects, specifically other magnets and magnetic materials, without having to come into contact with them.*]

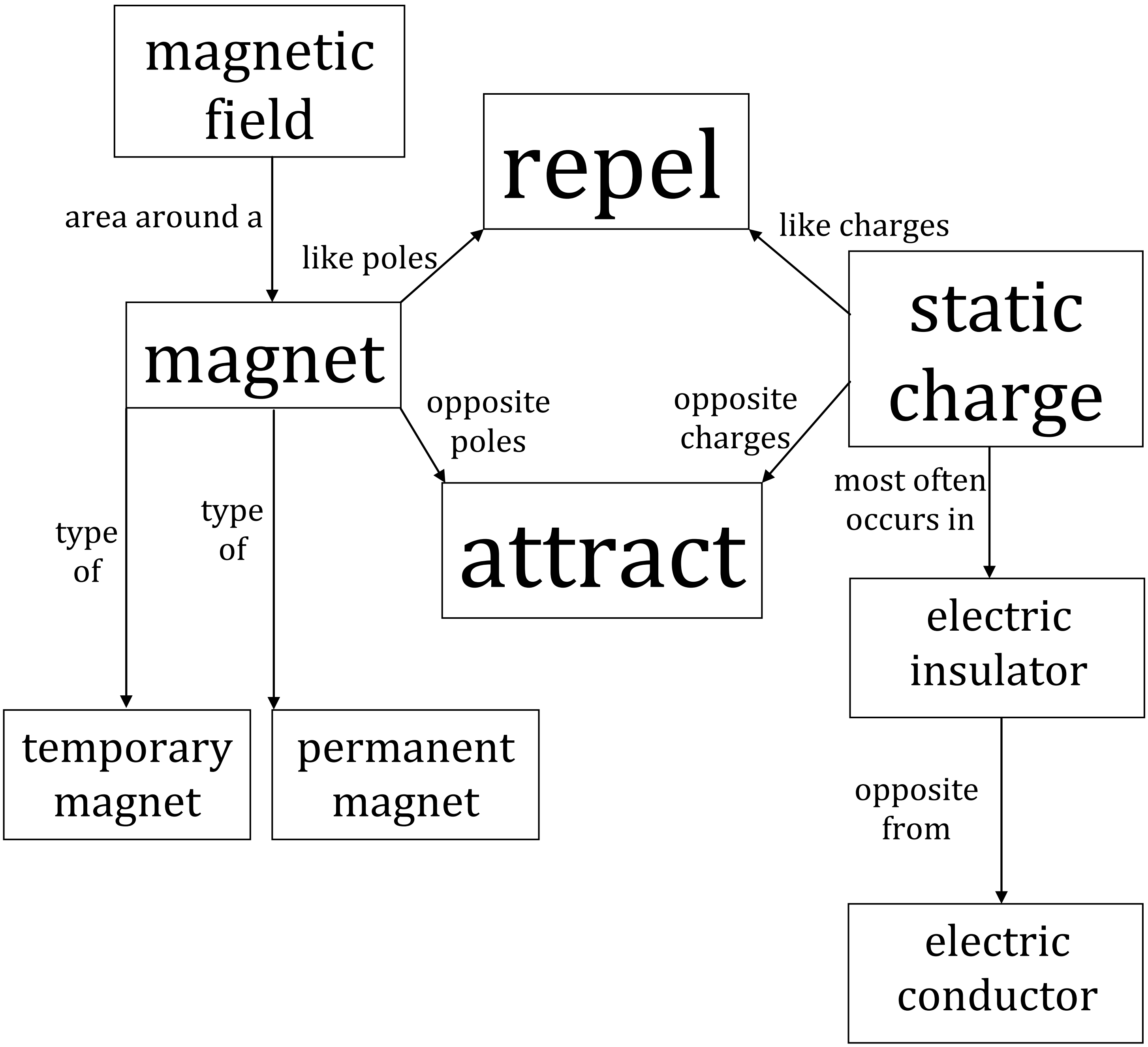
RI.3.4. Determine the meaning of general academic and domain-specific words and phrases in a text.	• In Section 1, the text describes electric charge. In your own words, what is electric charge, and what is one way it can occur? [*Electric charge happens when an object gains more electrons or protons, becoming negatively or positively charged. One way it can occur is when two objects rub against one another, and one object transfers electrons to the other object.*]
RI.3.7. Use information gained from illustrations and the words in a text to demonstrate understanding of the text.	• What are the diagrams on page 9 showing? [*The diagrams show how a negatively charged balloon is attracted to a positively charged wall, and how two negatively charged balloons repel each other, pushing apart.*]
Language	
L.3.2. Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.	• In Lesson 3, students use standard English capitalization, punctuation, and spelling as they work through the engineering investigation.
Speaking and Listening	
SL.3.1.A. Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.	• In Lessons 1, 2, and 3, students engage in Socratic dialogue before beginning the investigations and engineering activity. As a class, students read the reader, and then apply what they have read to new situations or real-life scenarios.

SL.3.1.B. Follow agreed-upon rules for discussions (e.g., gaining the floor in respectful ways, listening to others with care, speaking one at a time about the topics and texts under discussion).	• In Lessons 1, 2, and 3, students follow agreed-upon rules during the Socratic dialogue portion of the class, as well as during the activity portion of the lesson.
SL.3.1.C. Ask questions to check understanding of information presented, stay on topic, and link their comments to the remarks of others.	• In Lessons 1, 2, and 3, students actively engage in dialogue and in the activity portion of the lesson.
SL.3.1.D. Explain their own ideas and understanding in light of the discussion.	• In Lessons 1, 2, and 3, students contribute to the Socratic dialogue and during the wrap-up portion of the lesson, explaining their experiences and understandings.

Use this chart to keep track of how you are connecting science to the rest of your curriculum.

Unit Connections to ELA Common Core	Unit Connections to Math Common Core	Unit Connections to History/Social Studies

Unit 7: Appendix 3
Sample Concept Map



Unit 7: Appendix 4
Support for Differentiated Instruction
Next Generation Science Standards

Core Expectation	KnowAtom Assessment Strategies	Possible Primary Evidence
3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.	Low Entry Point • Make observations about the effects of electric or magnetic forces that act on objects without the objects coming into contact with one another. • Describe the basic rules of electric and magnetic forces: opposites attract and likes repel. At Grade-Level Entry Point • Conduct an investigation with different materials to support an explanation about the effects of electric or magnetic forces.	• "Static Charge Investigation" completed by student • "Magnetic Fields Investigations 1 and 2" completed by student • "Engineering" sheet completed by student
3-PS2-4. Define a simple design problem that can be solved by applying scientific ideas about magnets.	Low Entry Point • Describe how magnetic force between objects doesn't require that the objects be in contact with one another. • Define the problem to be solved with magnets. At Grade-Level Entry Point • Identify the factors that affect the size of the magnetic force (e.g., properties of objects, distance between objects, and orientation of magnetic objects relative to one another). • Include the criteria and constraints of the problem.	• video of student using the given scenario to come up with the problem facing A&B Factory • "Engineering" sheet completed by student

Core Expectation	KnowAtom Assessment Strategies	Possible Primary Evidence
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	<u>Low Entry Point</u> • Identify a problem that needs to be solved. • Recognize that scientific knowledge can be used to solve problems. <u>At Grade-Level Entry Point</u> • Define the constraints of a particular problem. • Define the criteria of a particular problem. • Describe how the solution will solve the problem.	• "Engineering" sheet completed by student • video of student sorting the relevant need for the scenario from a set of different options • video of student sorting the relevant criteria and constraints
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	<u>Low Entry Point</u> • Recognize that for any problem, there exist multiple solutions that could potentially solve the problem. • Recognize that some solutions will be more effective than others at solving the problem. <u>At Grade-Level Entry Point</u> • Use a systematic method for evaluating multiple solutions.	• "Engineering" sheet completed by student • student list of possible solutions that might solve the problem

Core Expectation	KnowAtom Assessment Strategies	Possible Primary Evidence
3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	<u>Low Entry Point</u> • Test and collect data from multiple, iterative design solutions. <u>At Grade-Level Entry Point</u> • Identify relationships among the data collected to determine which characteristics worked well and which didn’t.	• “Engineering” sheet completed by student

Unit 7: Appendix 5
Materials Chart*

	Lesson	Quantity	Notes	Used Again
Unit Kit Consumable				
Goggles	all	1 per student	safety	✓
Cardboard bases	1	shared	for electroscope arm	
Aluminum foil sheets	1	1 per team of 2	for electroscope foil	
Large paper clips	1 3	1 per team of 2 15 per team of 2	for electroscope hook for engineering challenge	
Large plastic cups (24 oz)	1	1 per team of 2	for electroscope support	
Non-drying clay	1	shared	for stabilizing paper clips	
Plastic cups (10 oz)	1, 2 3	1 per team of 2 3 per team of 2	for testing static charge, collecting iron filings, and engineering	
Graduated cups (30 mL)	2	1 per team of 2	for holding iron filings	
Poster paper	2	1 per team of 2	for observing magnetic fields	
Small craft sticks	3	10 per team of 2	for engineering challenge	
Large craft sticks	3	5 per team of 2	for engineering challenge	
Clothespins	3	1 per team of 2	for engineering challenge	
Dowels	1 and 3	1 per team of 2	for testing electroscopes and the engineering challenge	
Paint stirrers	3	1 per team of 2	for engineering challenge	
Felt sheets	3	1 per team of 2	for engineering challenge	
String	3	shared spool	for engineering challenge	
Small paper clips	2 3	1 per team of 2 5 per team of 2	for testing magnetic fields for engineering challenge	
Factory Test Templates	3	1 per team of 2	for testing magnetic devices	
Non-Consumable				
Plastic (PVC) rods	1	1 per team of 2	for testing electroscopes	
Wool cloth	1	1 per team of 2	for transferring static charge	
Glass plates	1	1 per team of 2	for testing electroscopes	
Bar magnets (small; 3 cm x 1 cm)	2, 3	2 per team of 2	for testing magnetic fields	
Bar magnets (medium; 2 cm x 1.5 cm)	2, 3	2 per team of 2	for testing magnetic fields	
Bar magnets (large; 4 cm x 2 cm)	2, 3	1 per team of 2	for testing magnetic fields	
Iron filings	2	shared	for observing magnetic field lines	

Bar magnets (long; 7.5 cm x 1 cm)	3	1 per team of 2	for testing magnetic fields	
Round magnets	3	1 per team of 2	for engineering challenge	
Clear plastic cylinder	3	1 per team of 2	for engineering challenge	
Timers	3	1 per team of 2	for timing prototype tests	✓
Teacher Tool Kit				
Scissors	1, 3	1 per team of 2	for cutting materials	✓
Invisible tape	1, 2, 3	1 per team of 2	for taping materials	✓
Hole punches	1	1 per team of 2	for punching holes in foil	✓
Rulers	1, 2	1 per team of 2	for measuring materials	✓
Hand-outs				
Student readers	1	1 per student	for "Static Charge Investigation," "Magnetic Fields Investigation 1 and 2," and "Engineering" sheet	
Visuals	Download			
Lesson 1	Parts of an Atom Visual, Static Charge Visual, Electroscope Visual			
Lesson 2	Magnets and their Magnetic Fields Visual			
Lesson 3	Magnets in Engineering Visual, Engineering Scenario Visual			

* The size of the bar magnets you receive in your kit may vary slightly from the dimensions shown in this unit.