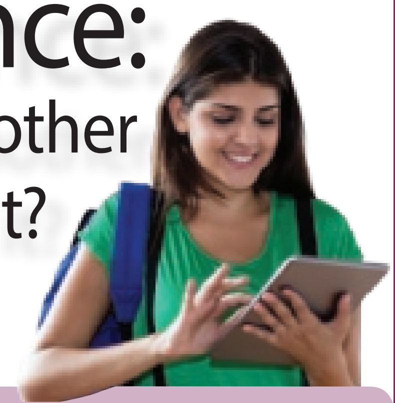
Science Literacy

Forces at a Distance:

How can a magnet move another object without touching it?



Teacher Guide

Core Knowledge Science®

GRADE 8

Core Knowledge®

This unit is a modified version of a unit that has earned the NGSS Design Badge. The sole instructional modification is the addition of Core Knowledge Science Literacy content. The modification has not been reviewed.

Forces at a Distance:

How can a magnet move another object without touching it?

Teacher Guide

Core Knowledge®

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BEFORE YOU BEGIN

Before introducing the unit, please become fully acquainted with the program instructional model and classroom routines by reading the online resource **Teacher Handbook: Overview of the Core Knowledge Middle School Science Program**.

Online Resources

Use this link to download the **CKSci Online Resources Guide** for this unit, which includes specific links to:

- the unit's comprehensive materials list
- a full unit pacing snapshot
- lesson guidance slides
- all other recommended resources.

www.coreknowledge.org/cksci-online-resources

Student Work Pages

All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources.

Student Books

All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources. Students also will use the Student Procedure Guide and the Science Literacy Student Reader throughout the unit.

UNIT OVERVIEW

How can a magnet move another object without touching it?

Music has a central place in the lives of young people. It has never been easier for them to listen to their favorite songs in the car, on the bus, or in the schoolyard. Middle school students spend countless hours cycling through playlists on their devices, using headphones or Bluetooth speakers that are designed and marketed to young people. Speakers, in their various forms, work with the simple movement of a speaker membrane, or speaker cone. But what causes this membrane to move? Can a tiny headphone do something similar to the subwoofer speaker in a car to play music? As speakers have evolved over time, one thing has remained the same: the use of magnets to vibrate the speaker membrane.

Students are presented with an anchoring phenomenon focusing on the vibration of a speaker and asked to think about what causes this vibration. The vibration of a speaker connects to a model of sound students have developed previously, but this new unit opens the door for students to investigate the cause of a speaker's vibration as opposed to the effect. Students dissect speakers to explore the inner workings, and they build homemade cup speakers to manipulate the parts of the speaker. They identify that speakers of all kinds have some of the same parts—a magnet, a coil of wire, and a membrane. Students investigate each of these parts to figure out how they work together in the speaker system. Along the way, students manipulate the parts (e.g., changing the strength of the magnet, number of coils, current direction) to see how this technology could be modified to apply to systems in very different contexts, like maglev trains, junkyard magnets, and electric motors.

Through a series of hands-on investigations, students

- develop and refine a model about forces (pushes and pulls) that includes magnetic forces interacting at a distance via fields that extend through space,
- revise a model for explaining magnetic forces to include electromagnets that act as permanent magnets in many ways but can be manipulated by changing the electric current,
- consider the transfer of energy in their model, and the connections between forces, energy and magnetic fields,
- plan and carry out a series of investigations to test how changes in one part of a magnetic system (e.g., number of coils, diameter of coils, strength of magnet) affect the magnetic forces in the system, and
- construct an explanation based on evidence to explain that magnetic fields extend through space and predict the strength and direction of magnetic forces.

Focal Disciplinary Core Ideas (DCIs): PS2.B; PS3.A

Focal Science and Engineering Practices (SEPs): Asking Questions and Defining Problems; Developing and Using Models; Planning and Carrying Out Investigations

Focal Crosscutting Concepts (CCCs): Cause and Effect; Systems and System Models

Building Toward NGSS Performance Expectations

MS-PS2-3: Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

MS-PS2-5: Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

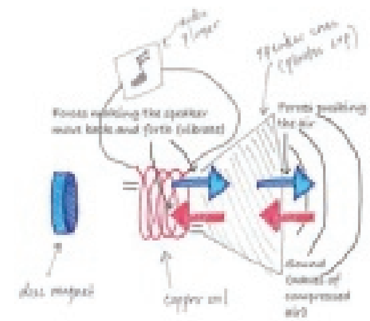
MS-PS3-2: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

UNIT STORYLINE

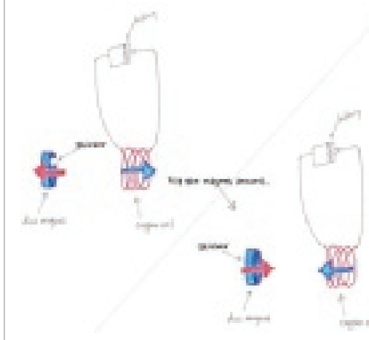
How students will engage with each of the phenomena

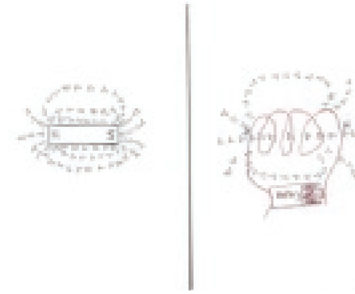
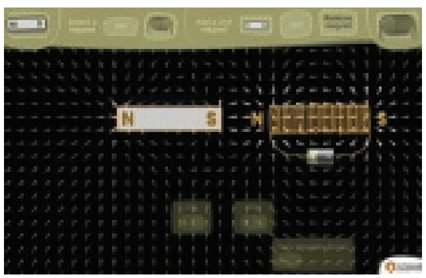
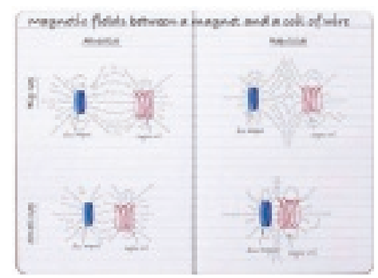
HANDS-ON/ LAB ACTIVITIES	VIDEOS OR IMAGES	DATA SETS	READINGS	COMPUTER INTERACTIVES

How can a magnet move another object without touching it?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 **4 days** **What causes a speaker to vibrate?** Anchoring Phenomenon	 *A speaker system with a magnet and a coil of wire moves back and forth without the parts touching.*	We dissect a store bought speaker and then build a homemade speaker. We develop an initial model to describe how interactions between parts of a speaker system cause sound without touching each other. Finally, we generate questions for our Driving Question Board (DQB) using a cause-effect scaffold that we will return to throughout the unit. We figure out: • A speaker is a system with parts that include a magnet, a coil of wire, and a speaker cone. • When the coil of wire is connected to a sound source, the speaker cone vibrates to produce sound, but only when a magnet is brought very near to the wire. • The magnet and the coil of wire do not need to be touching to make the speaker cone vibrate.	

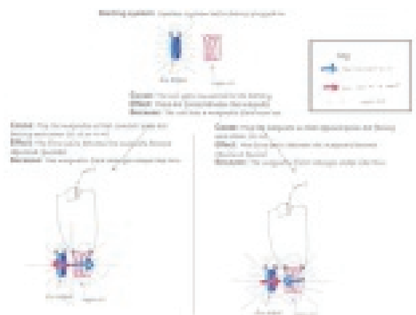
⇩ **Navigation to Next Lesson:** We identified the magnet and the coil as important parts of the system. In our next lesson, we can spend some time making observations of magnets and coils to find out more.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 2 **2 days** **What can a magnet pull or push without touching?** Investigation	 *A magnet interacts with metal but not with copper unless it is connected to a battery.*	We experiment with magnets, coils and other metal objects to establish that while certain metals do interact with magnets, including other magnets, the copper coil does not. We notice force pairs between the magnet and the coil only when the coil is hooked up to a battery. We figure out: • There are forces between the magnet and the coil when the coil is connected to the battery. • Just like in a system with two magnets, we can get both pushes and pulls (repulsive and attractive forces) between the magnet and the connected coil. • Just like in a system with two magnets, we can get the connected coil of wire and the magnet to switch the type of force they are producing (attractive vs. repulsive) if we flip the orientation of either one of them. • When the connected coil of wire or the magnet move, they have kinetic energy.	
⇩ **Navigation to Next Lesson:** We know from our Broken Things unit and our Sound unit that contact forces transfer energy during collisions. We want to know where the energy of the moving coil came from if the parts of the speaker are not touching.			
LESSON 3 **1 day** **How does energy transfer between things that are not touching?** Investigation	 *When we block the air between two magnets or remove it altogether, magnets still exhibit the same interactions when they get close to each other.*	We are wondering how energy could transfer between parts of the speaker when the parts aren't touching. We think the energy might be transferring through the air. We write two hypotheses that predict the cause-and-effect relationships we would observe if energy transferred between magnets through the air. We figure out: • The energy that makes magnets move when they get close to each other does not get transferred through air.	
⇩ **Navigation to Next Lesson:** We use evidence from two whole-class investigations to show that our hypotheses about the role of air are false. We aren't sure what's going on in the space between two magnets, and we decide we need some new ways to visualize what is going on in that space.			

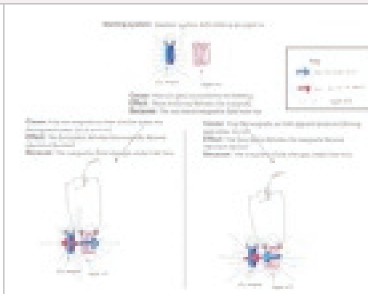
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 4 **4 days** **What can we figure out about the invisible space around a magnet?** Investigation	 *When we place test objects like iron filings or compasses near a magnet we see patterns in the direction that they move that we can model with diagrams and computer interactives.*	We wonder about the space around a magnet that seems to push and pull on certain things. We learn that this space is called a *magnetic field*. We decide to investigate the field with test objects, like iron filings and compasses. We learn what the magnetic field looks like and that the field is not the same in every location around a magnet. We figure out: • The space around a magnet has a particular 3-dimensional shape, which we call a *magnetic field*. • Test objects, like small bits of iron and compasses, are affected by the magnet if placed inside the magnetic field. • Test objects show us that the magnetic field is not the same in every location around the magnet and seems to weaken and disappear as you move farther away from the magnet. • Electromagnets also have a magnetic field, and if the wire is made into a coil, the magnetic field is similar to that of a bar magnet. • Forces in the field have a direction—out of or away from the north pole and into or toward the south pole.	
⇩ **Navigation to Next Lesson:** We wonder how the magnetic field responds when there are two magnets or a magnet and a coil of wire that are near each other.			
LESSON 5 **1 day** **How does the magnetic field change when we add another magnet to the system?** Investigation	 *When we add a second magnet to the computer interactive, the shape of the magnetic field changes depending on the orientation of the magnets to one another.*	We use a computer interactive to simulate the fields between a magnet and a coil for both attractive and repulsive forces at two different distances apart. We make diagrammatic models of the fields and come to consensus around how to represent the fields. We figure out: • When we look at the magnetic field around two magnets (or a magnet and a coil of wire), the magnetic field looks different than if we are looking at only one magnet. • When the forces are attractive (i.e., S-N or N-S), then the magnetic field connects in the middle with a line of pointers pointing in the same direction.	

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr><td></td><td></td><td>

When the forces are repulsive (i.e., S-S or N-N), then the pointers curve away from each other in the middle.
It was hard to tell what happens when we move the magnet and the coil closer together.

</td><td></td></tr>
<tr><td colspan="4">⇩ Navigation to Next Lesson: In our investigations throughout Lessons 2-5, we figured out that invisible magnetic fields are responsible for the interactions we saw between the magnet and the electromagnet in the speaker. Next time, we want to pause and put together some of our ideas to explain how this happens, which will also help us determine if there is anything else about how the speaker system works that we still need to figure out.</td></tr>
<tr><td>LESSON 6
3 days
How can we use magnetic fields to explain interactions at a distance between the magnet and the coil?
Putting Pieces Together, Problematizing</td><td>
In a speaker, forces transfer energy out of an invisible magnetic field and into the rest of the system, producing the movement that we observe as vibrations or sound.</td><td>We develop an initial model to describe how forces and energy transfer in magnetic fields explain cause-and-effect relationships between parts of a speaker system (magnet and coil of wire). We ask questions about how interactions between the magnet and the coil of wire cause sound without those parts touching each other. We figure out:

Forces in an invisible magnetic field produce the movement we observe between a magnet and an electromagnet without touching.
Flipping either magnet so that like poles are facing will change the magnetic field shape so that there will be repulsive forces between them.
Flipping either magnet so that opposite poles are facing will change the magnetic field shape so that there will be attractive forces between them.

</td><td></td></tr>
<tr><td colspan="4">⇩ Navigation to Next Lesson: We still have a lot of gaps in our model that we want to investigate, mostly around the electromagnet. How does it work? And how does it produce both pushes and pulls when it is connected to a music player instead of a battery? When we modeled the magnetic field for a big gap versus a small gap, the field changed, but we don't know exactly what this means in real life. We have some ideas. We want to push magnets closer together and observe the effect in real life.</td></tr>
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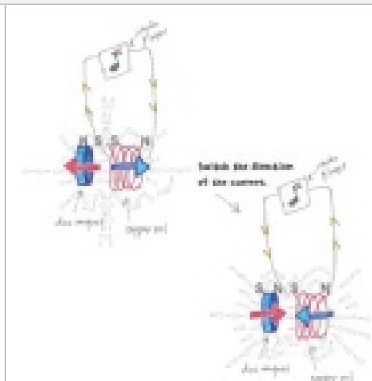
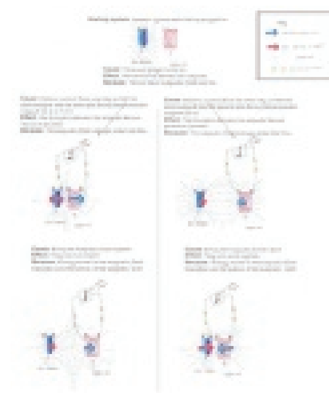
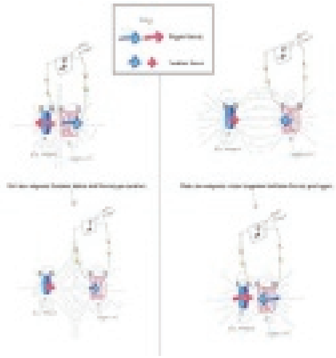
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr><td>LESSON 7
1 day
How does changing the distance between two magnets affect the amount of energy transferred out of the field?
Investigation</td><td>
A cart on a track with a magnet on it is repelled by another magnet mounted to a bumper and moves away from the bumper magnet after the cart is brought near it and then released.</td><td>We plan and carry out an investigation using a cart on a track to determine how changing the distance between two magnets that experience repulsive forces between them affects the energy transferred in a magnetic field between them. We use our results to explain how changing the distance between two magnets affects the amount of energy transferred into and out of the magnetic field. We figure out:
• When two magnets have repulsive forces between them and they are brought close together, kinetic energy is transferred into the magnets when they are released and they move back apart.
• When two magnets have attractive forces between them and they are moved apart, kinetic energy is transferred into the magnets when they are released and they move back together.
• Changing the distance between two magnets changes the amount of energy that can be transferred into and out of a magnetic field.</td><td></td></tr>
<tr><td colspan="4">Navigation to Next Lesson: We think energy might be transferring out of a battery into the electromagnet. But the speaker doesn't have a battery; it is connected to a music player. We aren't sure if those are the same thing or how they are related. We want to investigate that part of the system next.</td></tr>
<tr><td>LESSON 8
3 days
How does the energy transferred from a battery to a wire coil compare to the energy transferred from a computer to a speaker?
Investigation</td><td>
A speaker, a wire coil, an incandescent lightbulb, and a bicolor LED respond to an electric current provided by a battery vs. a sound app on a computer in some ways that are similar and some ways that are different.</td><td>We vary the volume and frequency of sounds being produced by a sound generator on a computer and observe the effects. We gather information using various materials including light bulbs to help explain how changes in the electric current produced by the computer result in changes to a magnetic field within the speaker system. We figure out:
• More batteries in the circuit give more current, which transfers more energy, and results in stronger forces.
• Electric current changes direction when you flip the battery in a circuit.
• Electric current from a music player can change direction.
• The frequency of the changes in current determines the pitch of the sound (previous idea from the Sound Unit).
• Current that flips direction causes the poles of the electromagnet to flip.</td><td></td></tr>
</table>

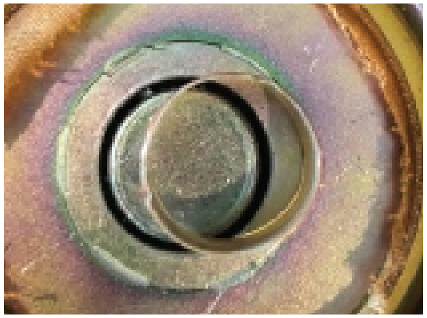
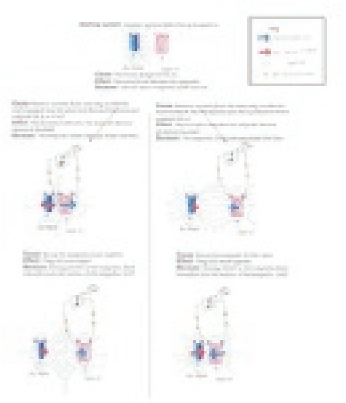
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
		• When the poles flip, the direction of forces (attractive vs. repulsive) flips in the field produced by the electromagnet.	
⇩ **Navigation to Next Lesson:** We are ready to put our energy related ideas together to update our models to help explain our speaker system further.			
LESSON 9 **3 days** **How do the magnet and the electromagnet work together to move the speaker?** Putting Pieces Together	 *In a speaker, forces transfer energy out of an invisible magnetic field into the rest of the system, producing the movement that we observe as vibrations or sound.*	We add to our list the cause-and-effect relationships. Then we construct a classroom consensus model to explain these relationships and how they work together to produce the patterns of movement we see in the speaker. After a brainstorm and a reading jigsaw, we wonder what we could do to make magnetic forces strong enough to lift trains and cars. We figure out: • Changing the current in the electromagnet changes the poles of the electromagnet and the shape of the magnetic field. • This will alternately produce force pairs between the magnet and the coil of wire that push them apart (repulsive force) and pull them together (attractive force), creating a vibration. • Energy is transferred into the magnetic field by the electric current flowing through the electromagnet and stored until it is converted into kinetic energy that transfers out of the system as sound energy.	
⇩ **Navigation to Next Lesson:** We learned about some very large applications for electromagnets. But our electromagnets can barely move a paper clip! We revised some of the questions on our DQB about the strength of magnetic forces that we want to investigate next in order to figure out how these very big devices can work.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 **3 days** **How does distance affect the strength of force pairs in a magnetic field?** Investigation	 *When we change the distance between two magnets, the force pairs between them (attractive or repulsive) get stronger when they are closer together.*	We co-design and then carry out an investigation using a digital scale to test the relationship between distance and magnetic force. We analyze graphs to determine the relationship between distance and magnetic force between two magnets. We figure out: • The magnetic field around a magnet (and thus an electromagnet) gets stronger when it is closer to another magnet, which means that the force between two magnets will be stronger as the magnets get closer together. • The force with which a magnet pulls or pushes on something attracted to it or repelled by it is dependent on the distance between the magnet and the object or between two magnets. • Where magnets are in relation to each other determines how much potential energy is in the system.	

⇩ **Navigation to Next Lesson:** We have a lot more questions about what causes changes in the strength of magnetic forces. We want to divide and conquer to answer those questions through investigations.

LESSON 11 **3 days** **What else determines the strength of the force pairs between two magnets in a magnetic field?** Investigation	 *When we increase the size of a permanent magnet, increase the number of coils in an electromagnet, or increase the current in an electromagnet, we make the forces between magnets stronger.*	We plan and carry out an investigation to produce data to support a hypothesis about what factors cause changes in the strength of magnetic forces. We figure out: • Magnetic forces can vary in strength across a field, and the whole field can get stronger and bigger when you make the magnet stronger. • Bigger magnets have stronger magnetic fields around them than smaller magnets of the same material, which means that the forces between two magnets will be stronger. • You can increase the current or the number of coils to get a stronger magnetic field around an electromagnet, which means that the forces between a magnet and an electromagnet will be stronger.	

⇩ **Navigation to Next Lesson:** We have figured out so much that we are ready to take stock of where we have been. We will also have an assessment for this unit where you will have an opportunity to demonstrate how much you have figured out about forces at a distance, designing investigations, and cause-effect relationships.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 12 **2 days** **What cause-effect relationships explain how magnetic forces at a distance make things work?** Putting Pieces Together	 *In a speaker, forces transfer energy out of an invisible magnetic field into the rest of the system, producing the movement that we observe as vibrations or sound.*	We took stock of how far we have come and applied our new ideas about the strength of forces to both the speaker and the other electromagnet applications we have considered. We revisited the DQB one last time to answer our remaining questions. Finally, we took an assessment. We figured out these ideas: • Forces transfer energy into and out of a magnetic field. • The amount of energy stored in the field depends on the strength of the forces (which are affected by several factors) and the arrangement of the magnets in the field. • Phenomena (like increasing the strength of magnetic forces) can have more than one cause.	
LESSONS 1–12 **30 days total**			

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstration, whether this is in a traditional science laboratory or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g., wearing safety goggles, non-latex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). Science investigations should always be directly supervised by qualified adults, and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstration. Prior to each investigation, students should also be reminded specifically of the safety procedures that need to be followed. Each of the lessons within the units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as taking down, disposing of, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgement form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgement form for middle school activities. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

Please follow these lab safety recommendations for any lesson with an investigation:

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a non-latex apron, and non-latex gloves during the set-up, hands-on investigation, and take down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip and fall hazard.
3. Follow your *Teacher Guide* for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing this activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.

Specific safety precautions are called out within the lesson using this icon and a callout box.

What are the Disciplinary Core Ideas (DCIs) in the context of the phenomenon?

In the **first lesson set**, students develop and use a model of magnetic fields in order to explain how magnets inside of a speaker interact to produce vibration and, therefore, sound. The link between vibration and sound is one that will come out of the previous unit: 8.2 *How Can a Sound Make Something Move? (Sound)*. If your class has not been through the Sound unit or a similar unit, you will need to establish this idea before teaching this unit or in Lesson 1 of this unit. In Lesson 2, students establish what kinds of objects interact with magnets and how to turn a coil of wire into a magnet by connecting it to a battery. In Lesson 3, students begin to consider energy as a factor in the system, in addition to forces. In Lesson 4, students develop a model for how the field around a single magnet predicts the forces that a test object will experience when brought near the magnet. They notice the directionality of the field and make a distinction between the shape of the field near the north pole of the magnet and near the south pole of the magnet. In Lesson 5, students extend this model using a computer interactive to simulate the field around two magnets. This lesson set develops the elements of the DCIs associated with **MS-PS2-5**.

Students now have a model for how a magnet and a coil of wire can interact to produce both attractive and repulsive forces. But in the speaker, these forces are constantly changing direction. Students' models cannot account for the changing direction of the forces.

This limitation in their models motivates the **second lesson set**. Up until now, students have been using a battery to make the electromagnet work. But in the speaker, there is a music player. The assumption has been that the battery is somehow providing energy to the system. Is this true, and if so, does the music player do the same thing? In Lesson 7, students use carts to establish more concretely the role of energy in the speaker system so they can trace it back to the battery. Then in Lesson 8, they investigate the electromagnet more closely to discover that it functions because of an electric current that travels through the wire from the battery. But is the battery a good analogy for the music player? Students plug a lightbulb into the music player to find out. They establish that an electric current is also coming from the music player but that this current, unlike that in the battery, is constantly changing. With this realization, they revise their model from the first lesson set to include a changing electric current. They are able to use this model to explain not only both attractive and repulsive forces in the speaker but how the changing current can create changes in the sound coming from the speaker (e.g., pitch). At the end of this lesson set, students have a model that explains how the speaker produces sound. This lesson set develops the elements of the DCIs associated with **MS-PS3-2**.

At the end of the second lesson set, there are still questions left on the Driving Question Board (DQB) related to other magnetic phenomena, and students have done research and readings on other applications for electromagnets beyond the speaker that their model does not explain well. These applications are all very big (e.g., maglev trains, electric cars, junkyard magnets) and require a lot of force. Our model for magnetic fields describes a speaker, but it doesn't transfer well to these other phenomena because the forces in the speaker are very small.

In the **third (and final) lesson set**, students design a set of investigations to modify various parts of the system in order to cause changes in the magnetic field that magnify the forces on a test object. They figure out a list of possible modifications, all of which increase the forces in the magnetic field. These include increasing the current in an electromagnet, increasing the number of coils in an electromagnet, increasing the number of permanent magnets in the field, decreasing the distance between the magnet and the test object, and increasing the diameter of the magnets (permanent and electromagnet) in the field. This lesson set develops the elements of the DCIs associated with **MS-PS2-3**.

This 6-week unit builds towards the following NGSS Performance Expectations (PEs):

- **MS-PS2-3:** Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
- **MS-PS2-5:** Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.
- **MS-PS3-2:** Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- **MS-PS2-2*:** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- **MS-PS3-1*:** Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
- **MS-PS3-5*:** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object (p. 61).

*These performance expectations are developed across multiple units. This unit reinforces or works toward these NGSS PEs that students should have previously developed or will develop more fully in future units. In the Scope and Sequence, PS2-2, PS3-1, and PS3-5 are first built in Unit 8.1. In this new context, students are considering the same relationships, but in the context of forces that are at a distance. Students will continue to explore these relationships in the context of gravity in unit 8.4.

The unit expands students' understanding of forces and energy transfer, which include these grades 6-8 DCI elements:

PS2.B: Types of Interactions

- ~~Electrical and~~ magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the ~~charges~~, currents, or magnetic strengths involved and on the distances between the interacting objects. **(MS-PS2-3)**
- Forces that act at a distance (~~electrical,~~ magnetic, ~~and gravitational~~) can be explained by fields that extend through space and can be mapped by their effect on a test object (a ~~charged object~~, a magnet, ~~or a ball, respectively~~). **(MS-PS2-5)**

PS3.A: Definitions of Energy

- A system of objects may also contain stored (potential) energy, depending on their relative positions. **(MS-PS3-2)**
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. **(MS-PS3-2)**

The parts of the DCI elements that are not developed in this unit are crossed out. In the Scope and Sequence, students will develop an understanding of gravity in Unit 8.4. Electricity is treated as an extension opportunity within this unit. The placement of this Unit 8.3 and associated units are shown in the Scope and Sequence document.

What should my students know from earlier grades or units?

This unit uses and builds upon Disciplinary Core Ideas (DCIs) and other science ideas that students should have previously developed in units 8.1 (*Broken Things*) and 8.2 (*Sound*):

- A sound wave needs a medium through which it is transmitted. **(MS-PS4.A)**
- A sound wave transfers energy through air. **(MS-PS4-1)**
- The change in motion of an object is determined by net force on the object. If total (net) force is not zero, motion will change. Greater mass means more force needed to change motion. More net force means more change in motion. **(MS-PS2.A)**
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. **(MS-PS3.C)**
- Forces on an object can also change its shape. All solid objects deform elastically (up to a point) when forces are applied to them. (not a DCI element, but important for modeling the phenomenon)
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction. **(MS-PS2.A)**

This unit reinforces and builds from the following DCI elements from grades 3 and 4.

3-PS2.A

- Each force acts on one particular object and has both a strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (only qualitative descriptions)

3-PS2.B

- Objects in contact exert forces on each other.
- Electrical and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.

4-PS3.A

- The faster a given object is moving, the more energy it possesses.
- Energy can be moved from place to place by moving objects or through sound, light, or electrical currents.

4-PS3.B

- Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- Energy can also be transferred from place to place by electrical currents, which can then be used locally to produce motion, sound, heat, or light.

4-PS3.C

- When objects collide, the contact forces transfer energy so as to change the objects' motion.

Students would benefit from having prior experience doing the following focal Science and Engineering Practices (SEPs) at the 3-5 grade-band level. They include the following:

Asking Questions and Defining Problems

- Ask questions that can be investigated based on patterns such as cause and effect relationships.

Developing and using models

- Develop and/or use models to describe and/or predict phenomena.
- Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.

Planning and Carrying Out Investigation

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.

Engaging in argument from evidence

- Construct and/or support an argument with evidence, data, and/or a model.

Having students familiar with using focal Crosscutting Concepts (CCCs) for this unit at the 3-5 grade-band level would be helpful. They include the following:

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change.

Systems and System Models

- A system can be described in terms of its components and their interactions.

Energy and Matter: Flows, Cycles, and Conservation

- Matter is made of particles.
- Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems.
- Energy can be transferred in various ways and between objects.

What are some common ideas that students might have?

Students will come into the unit with many ideas about forces and energy derived from previous classroom experiences, intuitive understandings of the way the world works, everyday experiences with movement, and the conversations they have had with parents, friends, and family members.

Some relevant ideas about **energy** that students may come into the unit with include the following:

1. Energy is lost when something stops moving. An object at rest has no energy.
2. Engineered devices can "make" or "use up" energy.
3. Energy is certain types of matter, such as food, kerosene, or gasoline.
4. Energy transformations are fundamental, for example, thermal energy is a different "kind" of energy than the energy of a moving ball.
5. Doubling the speed of a moving object doubles the kinetic energy.
6. Energy is a "thing." It is difficult to imagine an "amount" of an abstraction.
7. The terms *energy* and *force* are interchangeable.

Some relevant ideas about **forces** that students may come into the unit with include the following:

8. Force can be transferred from one object to another (like energy).
9. Force runs out, which is why an object in motion on Earth will gradually slow down and stop.
10. Force requires a living thing to exert it—a push or a pull from a human or another animal.
11. Constant motion requires constant force.
12. The amount of motion is proportional to the amount of force.
13. If something does not move, a force must not be acting on it.
14. Direction of motion is the same as the direction of the force.

Some relevant ideas about **magnets** that students may come into the unit with include the following:

15. All metals are attracted to magnets or are somehow magnetic.
16. All magnets are made of iron.
17. Anything that sticks to something else is a magnet, for example, paint sticking to a wall or tape sticking to paper.
18. The magnetic and geographic poles of Earth are located at the same place.
19. The magnetic pole of Earth in the Northern Hemisphere is a North Pole, and the pole in the Southern Hemisphere is a South Pole.
20. Only magnets produce magnetic fields.
21. A magnetic field is a real thing made up of lines that surround a magnet.
22. A magnetic field only exists in between two magnets.
23. Energy or force transfers between magnets through moving air.

It is valuable to think of ideas like these not as misconceptions that need to be erased but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board. For example, in Lesson 3 we are expecting that some students will suggest that energy transfers through air in the speaker system (see relevant idea 23 above). Regardless of if the idea is wrong or right, this is a well-informed idea based on our ideas about energy transfer from the Sound unit and from experience (we see that the wind can make things move and transfer energy, for example). Students who put forward this theory are transferring content knowledge and exercising scientific reasoning in a productive way.

Simply telling students that the energy does not transfer through the air in this case and explaining that energy transfers through a magnetic field is not as productive as investigating the inaccurate theory and building evidence against it that will help students construct a new, more accurate conceptual model for magnetism. So in this unit (Lesson 3), students spend time exploring the claim that energy is transferred between magnets through the air in order to build evidence for a more scientific conceptual model that includes invisible magnetic fields.

What modifications will I need to make if this unit is taught out of sequence?

This is the third unit in 8th grade in the Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier or later in the middle school curriculum. These include the following adjustments:

- If taught before Unit 8.1, supplemental teaching of the definitions of *forces* and *energy* would be required, particularly in the context of physical pushes and pulls (contact forces). These ideas are fundamental to the model of forces and energy in a magnetic field that students need to build.
- If taught before Unit 8.1 (or at the start of the school year), supplemental teaching of classroom norms, setting up the Driving Question Board, and asking open-ended and testable questions would need to be added. (These supports are built into 8.1.)
- If taught before Unit 8.2, supplemental teaching of what a sound is and how sound travels would be required, with an emphasis on how movement back and forth creates the physical pushes necessary to move air so that sound waves can transfer energy. These ideas are fundamental to students' understanding of the anchoring phenomenon in this unit.

What are prerequisite math concepts necessary for the unit?

In this unit students will collect, manipulate, and analyze data from several investigations. In Lesson 7 students will calculate rate of change from data collected and organized in a table. They will interpret this rate as the speed of a cart moving along a track. Data organization and analysis in Lessons 10 and 11 include graphing tabular data in two quadrants of the coordinate plane and interpreting the meaning of data in graphs.

Prerequisite math concepts from students' math classes include the following:

- CCSS.Math.Content.7.PR.1. Compute unit rates associated with ratios of fractions, including ratios of lengths, areas, and other quantities measured in like or different units.
  - In their 7th grade math classes, students have experience in determining rates of change from quantities where units are different, and they frequently calculate average speed. Students also begin to algebraically manipulate the variables in the equation for speed ($s = d/t$) and can determine any of the three when given the other two. Helping students focus on units needed for the desired quantity will minimize errors.
- CCSS.Math.Content.6.NS.C.8. Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.
  - In 6th grade, students are introduced to graphing points in all four quadrants of the coordinate plane and frequently use direction as an analogy. For example, if the origin of the graph is a starting point, walking north and west would result in a location in quadrant II. In Lessons 10 and 11 students consider the symmetry of data graphed in quadrants I and IV across the y-axis. The idea of reflection across an axis is not introduced until 8th grade, so be sure to check with math colleagues about the timing of this concept.

TEACHING SCIENCE LITERACY

How does the Core Knowledge Science Literacy routine integrate with the unit investigations?

The Core Knowledge Science Literacy Student Reader and the weekly Science Literacy routine layer varied reading opportunities into the science unit. In their lives after graduating from high school, most students will not become scientists. They will no longer routinely participate in guided investigations to figure out how phenomena work. They will, however, read text about science and scientific claims, day in and day out. The ability to learn and think about science through reading is a skill unto itself and is important in tandem with investigative learning. It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of misinformation on social media. Detection and construction of well-reasoned explanations are important not just in science, but throughout everyday life. Using claims and evidence in reasoning is the way that thoughtful people think about things, and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

Throughout the course of the unit's investigative lessons, students write in their science notebooks in some fashion almost daily, and significant emphasis is placed on the speaking and listening communication threads of the CCSS. The instructional design of the investigations is deliberately light on having students access disciplinary core content through text. NGSS emphasis is on students investigating phenomena along the storyline, so students' interaction with text within lessons is minimal and in service to the unit's storyline. The Science Literacy routine is integrated to exercise students' ability to interact with text about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied by a brief but thoughtful writing exercise.

The subject matter of the reading selections ties back to the unit, but the timing for the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

When is it done within a unit?

The Core Knowledge Science Literacy Student Reader includes one reading collection per week for every week of the unit. A week's reading collection relates to the lessons completed in the previous week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading selection. The products are varied in form, and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single, thoughtfully reasoned, and well-constructed paragraph.

Put Yourself in This Scene

Literacy Objectives

✓ Initiate thinking about the need to evaluate information in text and images.

Literacy Exercises

- Read a brief selection to pique interest, launch discussion, and begin to frame expectations.

Instructional Resource

Student Reader

Preface

Science Literacy Student Reader, Preface
"Put Yourself in This Scene"

No Prerequisite Investigations

The reading of the Preface is appropriate during the first week of unit instruction. The reading does not preemptively tell students facts about the topic that they are intended to learn throughout the course of their investigations.

Standards and Dimensions

NGSS Performance Expectation MS-PS2-3: (Building toward) Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

Disciplinary Core Ideas: PS2.B: Types of Interactions; **PS3.A:** Definitions of Energy

Science and Engineering Practices: Asking Questions; Constructing an Explanation

Crosscutting Concepts: Cause and Effect; Systems and System Models

CCSS

English Language Arts

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. No Core Vocabulary terms are highlighted in the Preface.

magnet

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

science fiction **science literacy**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the Science Literacy Student Reader.
- Friday: Set aside time at the end of the week to facilitate a brief discussion about the reading.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations.

MONDAY

- Let students know that for the Science Literacy routine, they will read independently and then complete short writing assignments. The reading selections relate to topics they will be exploring in their Forces at a Distance unit science investigations.
- The reading and writing will typically be completed outside of class (unless you have available class time to allocate).
- The first week's reading is a short introductory segment in the book, and there is no accompanying writing exercise as the unit is getting started.
- The class will discuss the reading together at the end of the week.

SUPPORT—The Preface is written at approximately Lexile 1100–1200, which leans toward the high end of the expected text complexity band for middle school. You may wish to introduce a word identification and comprehension convention into your routine to support struggling readers. Hang an envelope near the door with the label, "When we talk about the next reading selection, I could use a little more help understanding the word(s). . . " Encourage students, as they are reading, to jot words, phrases, or sentences that they are unclear about onto small scraps of paper and tuck them into the envelope at any time preceding the discussion of the reading. Whenever you facilitate class discussion about a reading selection, check the envelope first, and layer in added examples and repeat definitions to help students build comprehension and fluency for terms or complex sentences about which they have revealed they are uncertain.

3. Facilitate discussion.

Facilitate a brief class discussion about the Science Literacy Student Reader Preface, entitled "Put Yourself in This Scene."

Pages 2–3 Suggested prompts	Sample student responses
How would you summarize the "scene" referred to in the title?	*There are a lot of things that we don't even think about that use magnetic force. If all magnets stopped working, it would affect electrical appliances, motors, cell phones, and speakers.*
Why do you think life on Earth would end without magnets?	*Many modern conveniences that we rely on would not work.*
How do you use magnets?	*We have refrigerator magnets and some magnetic toys. But from this selection, there are a lot of ways we use magnets that I don't really know about.*
What do you know about magnetic forces?	*Magnets attract some types of metal but not other types of metal or other materials like paper or skin.* *Two magnets can push against (repel) each other.*

Student Reader

Preface

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

EXTEND—Make a class list of different things that students think use magnets for energy. Review this list at the end of the unit to see if any of their ideas have changed.

KEY IDEA—Point out that understanding how magnetic forces work has inspired a lot of innovations in telecommunications, electric motors, and speaker systems, among many other things. Both the investigations and the reading selections in the unit ahead will help students advance to a place where they have more knowledge to apply to the scenario, and they will circle back at the end of the unit to the topic of magnetic forces that can move other objects without touching.

What causes a speaker to vibrate?

Previous Lesson

There is no previous lesson.

This Lesson

Anchoring Phenomenon

4 DAYS

We are introduced to an anchoring phenomenon: a speaker vibrating using a magnet and a coil of wire. We dissect a speaker to identify the important parts of the system. Then we make a speaker that uses the same parts as the store-bought speaker. We brainstorm how magnets and electricity in the coil of wire could work together to cause the speaker to vibrate. This sparks a broader set of questions about magnets, electricity, and forces, which helps us form our Driving Question Board (DQB). We use a cause-effect scaffold to develop additional questions that focus on cause-and-effect relationships in the system.

Next Lesson

We will experiment with several objects to establish that while certain metals do interact with magnets, including other magnets, the copper coil will not until it is connected to a battery. We will change the direction of these forces by changing the orientation of either the magnet or the coil of wire.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Develop an initial model to describe how interactions between parts of a speaker system (magnet and coil of wire) cause sound without those parts touching each other.

Ask questions about how interactions between parts of a speaker system (magnet and coil of wire) cause sound without those parts touching each other.

What Students Will Figure Out

- A speaker is a system with parts that include a magnet, a coil of wire, and a speaker cone.
- When the coil of wire is connected to a sound source, the speaker cone vibrates to produce sound, but only when a magnet is brought very near to the wire.
- The magnet and the coil of wire do not need to be touching to make the speaker cone vibrate.

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	15 min	**INTRODUCE THE SPEAKER** Observe a slow-motion video of a speaker playing music. Brainstorm how to investigate the force inside the speaker that causes it to vibrate.	A-C	Speaker in slow motion video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
2	10 min	**SPEAKER DISSECTION DEMO** Dissect a speaker and make observations of the important parts inside the speaker.	C	Speaker Dissection Demo
3	7 min	**MODEL THE SPEAKER SYSTEM INDIVIDUALLY** Develop individual models in students' notebooks to explain how the parts of the speaker work together to cause forces that vibrate the speaker.	D	
4	13 min	**IDENTIFY THE MOST IMPORTANT PARTS OF THE SYSTEM** Students share their ideas about what parts of the system are important and why.	E	chart paper, markers
				End of day 1
5	10 min	**NAVIGATION TO THE HOMEMADE SPEAKER** Introduce students to the homemade speaker by playing music using your pre-assembled demonstration speaker. Orient students to their task for building the speaker.	F-G	preassembled homemade speaker, 4 small disk magnets, stereo audio auxiliary cable with both ends stripped, 1 pair alligator clips, music-playing device
6	20 min	**BUILDING A HOMEMADE SPEAKER** Build a homemade speaker that uses only a magnet, a wire, and a plastic cup to play music.	G-H	Building a Homemade Speaker
7	15 min	**COMPARING SPEAKERS** Discuss similarities and differences between the store-bought and homemade speakers, focusing on the relationship between the magnet and the coil of wire.	I	markers
				End of day 2

Part	Duration	Summary	Slide	Materials
8	25 min	**DEVELOP AN INITIAL MODEL FOR THE SPEAKER** Have students review the classroom norms and set expectations for their work together on a consensus model. Prompt students to pick one norm to focus on for today.	J-K	chart paper, markers, Communicating in Scientific Ways handout, Initial Speaker System Model poster (developed in this lesson)
9	12 min	**BROADENING TO RELATED PHENOMENA** Share what we already know about magnets, wire, and electricity by brainstorming objects that use these same things to work.	L	chart paper, markers, Related Phenomena poster (developed in this lesson)
10	8 min	**NAVIGATION** Students look more closely at the space between the magnet and the wire and record the unit question.	M-N	
				End of day 3
11	15 min	**DEVELOP QUESTIONS FOR THE DRIVING QUESTION BOARD** Students use cause-and-effect to develop questions about the speaker system and its parts.	N-S	sticky notes, markers, chart paper, Initial Speaker System Model poster (developed in this lesson), Related Phenomena poster (developed in this lesson)
12	15 min	**DEVELOP THE DRIVING QUESTION BOARD** Convene a Scientists Circle to construct the Driving Question Board (DQB) around students' questions.	T	sticky notes with questions written on them, DQB (developed in this lesson), Initial Speaker System Model poster (developed in this lesson), Related Phenomena poster (developed in this lesson)
13	13 min	**PLAN IDEAS FOR INVESTIGATIONS** Create an Ideas for Investigations poster and record the class's thoughts on how to figure out the answers to our initial questions as we move forward.	U	chart paper, markers, Ideas for Investigations poster (developed in this lesson)
14	2 min	**NAVIGATION** Motivate the investigations that follow.		
				End of day 4

Lesson 1 • Materials List

	per student	per group	per class
Speaker Dissection Demo materials			• speaker to dissect • screwdriver • scissors or a knife • index cards • Dissecting a Speaker - Unit 8.3 Forces at a Distance Lesson 1 if you choose this alternative to the dissection demo (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • pre-dissected speaker if you choose this alternative to the dissection demo
Building a Homemade Speaker materials		• 9-oz. plastic cup • 12 feet 28-gauge copper wire • D-cell battery to wrap wire around to make a coil (or a tube with approximately 1-inch diameter) • small piece of sandpaper • 4 small disc magnets • 3-4 inches of tape • music-playing device	
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • sticky notes • markers • sticky notes with questions written on them		• Speaker in slow motion video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • music-playing device • chart paper • markers • preassembled homemade speaker • 4 small disk magnets • stereo audio auxiliary cable with both ends stripped • 1 pair alligator clips • Communicating in Scientific Ways handout

			• Initial Speaker System Model poster (developed in this lesson) • Related Phenomena poster (developed in this lesson) • DQB (developed in this lesson) • Ideas for Investigations poster (developed in this lesson)

Materials preparation (60-90 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the Speaker in Slow-Motion video ahead of time. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Consider replacing the image in slide A with a model for the speaker developed by your class in Unit 8.2: Sound.

Prepare chart paper for posters. Consider titling posters (e.g., Initial Speaker System Model, Related Phenomena, Ideas for Investigations) ahead of time.

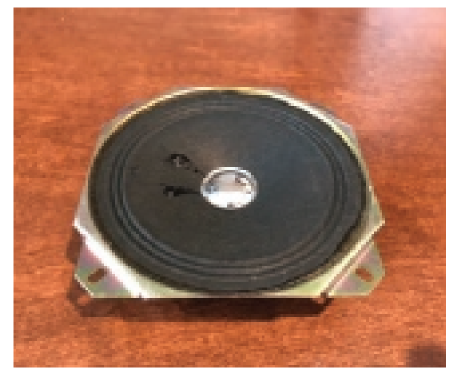
Download the *Communicating in Scientific Ways* file from the online resources and post in your classroom or add to students' notebooks. The file can be used as a poster or a handout.

Online Resources

Day 1: Speaker Dissection

- **Group size:** Whole class
- **Setup**

1. The speaker dissection is best as a real-time investigation to do with your students. However, there are two alternative approaches to the speaker dissection: using a previously dissected speaker or playing a video of a speaker dissection. If you select an alternative approach, the advance preparation is different. Watch the speaker dissection video yourself to orient yourself to how you would do it as a real-time investigation with students. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
2. If you want a larger speaker to dissect, use an old stereo speaker purchased at a thrift store (~$5). Otherwise, use the 4-inch speaker provided in your kit.
3. If you purchase a speaker from a thrift store, remove the grill and housing prior to the dissection. If there is an amplifier inside, remove this too if possible. This will speed the dissection and focus students on the fundamental parts of the speaker and not the exterior components.
4. Have scissors and a screwdriver handy to aid in the dissection.



Day 1: Homemade cup speaker

Group size: Whole class

- **Setup**
  1. Build a homemade speaker using the steps in the teacher guide. Check ahead of time to make sure it works. Use the video if you are having trouble removing the enamel from the wire. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  2. Set up one or two sound testing stations where groups of students can easily hook their cup speaker to a device to test whether their speaker works. Consider having more than one station if you have a large class and many groups. Watch Lesson 1 - Video C - Sound test cup speaker to see how this will work. The station(s) will need the following setup: (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
     - a device that can play music and has a standard audio jack output (e.g., computer, tablet, old phone, Walkman)
     - preselected audio to play on the device, like a song (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), or choose a song or audio file from your own music library. Preview the music choice to ensure it is appropriate for your students.
     - stereo audio auxiliary cable (two male ends) to connect to the cup speaker (Watch Lesson 1 - Video A - Prep for cup speaker to see how to prep the cables and other cup materials.) To prepare the cables, do the following: (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
       - Cut the stereo audio auxiliary cable in half. This will give you 2 pieces of audio cable that could be used at 2 testing stations. Each will be about 2 feet in length.
       - On each half, strip the black plastic covering to expose the two colored wires inside (one white and one red) that also will have plastic covering. They may be surrounded by either a layer of foil or some very fine copper fibers. This is a layer of shielding that needs to be cut off; remove that material if it is there. Strip at least 1 inch of the red and white plastic coverings off of each to reveal the copper wire inside. There may be a third wire (yellow) that is the ground wire. Strip the end of the yellow covering too.
       - Connect each exposed copper wire end to an alligator clip (red wire to one clip, white wire to the other clip; if there is a yellow wire, run it with either the red or white wire). Make sure the red and white wires are not in contact.
       - Students will hook their cup speaker to the other end of the alligator clip.
       - Watch the video to see how to coil the wire and prep the electromagnet for the speaker. It is suggested that you have students complete this step in class; though, you can choose to prep these coils ahead of time if necessary. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
       - Note there is another cable option demonstrated in this video that uses other materials in lieu of the stereo audio auxiliary cable. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

- Prepare lab bins for holding and transporting the cup speakers for each group. Each group of students will need a bin of supplies. The bin should include 1 9-oz plastic cup, 1 D-cell battery (or 1-inch tube), 1 2″-×-2″ piece of sandpaper, and 12 feet of magnetic wire (28 gauge). Groups also need access to tape to attach the coil of wire to the bottom of their cups.
- Watch the video to get an idea of how students will build their speakers. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- Read more about building the homemade cup speaker at the video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

Vibrations from a speaker cone are due to an external force exerted on the speaker cone. This force comes from interactions between parts inside the speaker. The main parts of any speaker include a magnet and a coil of wire nestled near the magnet. The magnet and wire are not touching, but they are very close to each other. A speaker can work with any magnet and coil of wire hooked up to the two signal output lines from an electronic music player as long as the magnet is placed near the wire.

In the next several lessons, students will discover that magnets exert forces on some objects without touching those objects, such as an attractive force on some metals, which is a pull between the magnet and the metal object. This is probably something that many students have figured out intuitively already, either through experience with refrigerator magnets or from earlier grades. Students may also know that if you reverse the orientation of the magnets (the poles), you can get either a push or a pull occurring between them. Many students will likely believe that magnets attract all metals, which is a productive idea to investigate in Lesson 2. Having a shared experience to make these ideas explicit in Lesson 2 and establish explicit patterns will help students make connections between their intuitive understanding of what magnets do and their emerging ideas about forces and energy.

Throughout this unit, students will be reminded of what they learned in Unit 8.1 “Why do things sometimes get damaged when they hit each other?” (Broken Things), about paired forces (Newton’s third law): When the magnet puts a force on the coil of wire, the coil of wire also puts a force on the magnet. They will use the idea that forces can transfer energy to make something move to think about the system in terms of energy transfer from a magnetic field into the moving speaker.

Students bring a model for how contact forces interact with each other to the study of this unit. They will have knowledge about how balanced and unbalanced forces acting on objects can deform objects and how unbalanced forces on an object result in changes to the motion of that object. They will readily know that a force can be a push or a pull. And they will know that any sound source that vibrates must be moved or deformed by either a push or a pull. This includes the speaker cone.

Where We Are NOT Going

Students have developed a model for sound in Unit 8.2 “How can a sound make something move?” (Sound) that includes how collisions among particles of air (or other medium) result in matter compression bands spanning across space that propagate across the medium over time. They may believe the speaker works because there are similar particle collisions happening in the air between the magnet and the wire. Over time students leave this model behind and figure out that the magnet and wire interact with each other even in a vacuum where no air exists between them (Lesson 3).

1. Introduce the speaker.

15 MIN

Materials: science notebook, music-playing device Lesson 1 Speaker in slow motion (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Elicit initial ideas to make connections to the unit on sound. Begin by revisiting a phenomenon students saw in the unit *How can we detect sound from a distance?* to engage students' ideas about how speakers work. Say, *Ever since we finished learning about sound, I can't help noticing speakers everywhere I look.* * *We use speakers every day. What do we already know about how speakers make sound?* Elicit 2-3 student responses. Then focus students' attention on **slide A** (you can replace the image on the slide with your class model for the speaker). Review the consensus model from Unit 8.2 Sound. Focus on what students figured out about the speaker.

Say, *Let's go back to some of the ideas we had about speakers. We decided that for anything that produces sound, there has to be a force that is applied to the sound source to deform or bend it to get it to start vibrating. We identified what that force was for many instruments, but I don't think that we ever identified what the force was that was being applied to the speaker that caused it to vibrate.* *

Display **slide B**, which asks, *How could we investigate what is causing the speaker to vibrate?* Ask students to turn and talk with a partner for a minute to share ideas.* Then regroup to share out. Listen for student ideas about investigations, such as these:

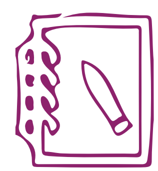
- We could make observations of a speaker vibrating.
- We could watch a slow-motion video of a speaker to see where the force is happening.
- We could ask someone who makes or installs speakers.
- We could take the speaker apart and look inside.

Observations of a speaker. Tell students that the class can do some of these investigations now to gather more information about the force, such as viewing the slow-motion video they may have seen in the previous unit about sound propagation. As you pull up the video, tell students to find a new page in their science notebook and label it "Observing a Speaker in Slow Motion." Under the title, they should create a table like the one on **slide C** with columns "What I notice" and "What I wonder." They will use this table to record observations from the video and any questions that they think about while they make their observations.

Science Notebook

This is the first use of the science notebook for the new unit. You may need time to organize a new section in the notebook. How to set up the section will vary depending on how you've structured the components of your notebooks, such as the table of contents and how to note the start of a new unit. It is recommended to have students do the following:

- Reserve a blank page at the start of the unit, to be titled on day 4 of this lesson when students are given the unit question.



*** Attending to Equity**

Students will find the anchoring phenomenon more compelling if it is presented in a meaningful context. Ask students where they see speakers every day. Students may suggest the speakers in their phones, their headphones, the school loudspeaker, a bluetooth speaker, or a sound system at home.

*** Strategies for This Initial Ideas Discussion**

The purpose of this brief discussion is to (1) give students a chance to reflect on what they already know about forces and sound from previous units and (2) motivate the dissection of the speaker by revealing a gap in what we know (the cause of the force in the speaker). Ask, *what causes the force in a drum (or a recorder)?* This will engage students in retrieving ideas from the previous units and remind the class that forces are typically caused by <u>contact</u> (between the hand and the drum or the air and the recorder).

- After the title page, reserve 2 pages (4 pages front-to-back) for the table of contents (unless all tables of contents are at the front of the notebook).
- Reserve 10 pages (20 pages front-to-back) for the Progress Tracker pages.
- Number the pages so everyone begins the first investigation of the unit on the same page number.

Remind students that the notebook is their tool for recording their observations, evidence, and ideas to share with the classroom community. They should see it as a space to brainstorm and record their thinking as well as a place to show how their thinking changes as they learn more.

For more information on *Science Notebook Management*, refer to this section of the *Teacher Handbook*.

Play the Speaker in Slow-Motion video with the sound muted. Have students add to their observation table as they watch the video. Then, play the video a second time with the sound on so that students can match their visual observations with auditory ones. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Prompt students to record additional observations and questions. Give students time (about 1 minute) to share their observations with a partner, then have 2 or 3 students share what they discussed with the whole group.*

Ask students to share new ideas they have about what is causing the force(s) that vibrate the speaker. Listen for student responses like the following:

- Electricity from the computer/device causes it.
- Some kind of electronics inside the speaker causes it.
- Something inside is pushing (or pulling) on it.
- There are air particles moving/vibrating inside it, which is vibrating the speaker. There is sound moving down the wires to the speaker.

Transition to the speaker dissection. This transition will vary depending on whether you plan to (1) dissect a speaker in real time, (2) use a speaker you have already dissected, or (3) play a video of a speaker dissection.

- **If you plan to dissect the speaker in real time,** say, *Some of you mentioned wanting to take a speaker apart and look inside. Let's try that out. Let's make some additional observations of the parts we find inside of it and see if that can help us figure out more about how it works.*
- **If you plan to use a previously dissected speaker,** say, *Some of you mentioned wanting to take a speaker apart and look inside. I thought you might be interested in that, so I took one apart earlier. Let's make some additional observations of the parts we find inside of it and see if that can help us figure out more about how it works.*
- **If you plan to play a video,** say, *Some of you mentioned wanting to take a speaker apart and look inside. I don't have an extra speaker to do this, but I do have a video of someone taking apart a speaker, and the video could give us clues about what's inside. Let's make some additional observations of the parts we find inside of it and see if that can help us figure out more about how it works.*

*** Attending to Equity**
It is important to organize activities in ways that create opportunities for students to engage in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a whole-class discussion). This is especially beneficial to emergent multilingual students. Strive to give students an opportunity to share their ideas with one or two peers before going public with the whole class. Encourage small groups of students to communicate using any combination of the languages and registers with which they feel comfortable.

*** Attending to Equity**
An optional, second investigation is to connect a speaker to your music-playing device and play a song for your students. If students lightly touch the speaker, they can feel the vibrations. This could be particularly powerful for students who are visually or hearing impaired. Use the stereo audio cable and alligator clips along with a 4-inch speaker (this could be the same speaker you plan to dissect) to play the music. If you select this option, plan for an additional 5-10 minutes for this part of the lesson.

2. Speaker Dissection Demo

10 MIN

Materials: Speaker Dissection Demo, science notebook

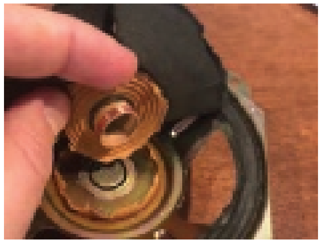
Observations of a dissected speaker. Have tools handy for taking the speaker apart, such as a screwdriver and scissors or a knife. Remove the grill and housing from the speaker ahead of time. This will save time to focus on the important parts inside the speaker. Ask students to gather around for the dissection or project the dissection on a document camera. Before you begin, ask students, *How could taking a speaker apart help us figure out what is causing the force that is vibrating the speaker? What do we think we're going to find inside the speaker?* Accept all responses.*

Alternate Activity

There are three options for observations in this activity: (1) Dissect a speaker in real time, (2) use a previously dissected speaker, or (3) use a video of a speaker dissection. The recommended option is to dissect a speaker in real time with your students, which is how the activity is written below. The benefit of doing a speaker dissection as a class is that it builds a sense of mystery about what's inside the speaker and it involves students in the physical dissection of the speaker. It also communicates to students that their ideas for investigating the speaker, which they shared at the start of this lesson, are motivating the need to look inside the speaker. However, if you teach several class periods of science and you want to dissect only one speaker for this activity to be reused across your classes, consider the alternative of dissecting a speaker ahead of time and allowing students to make observations of it. This is a good option if you have limited supplies. You may also consider using the Dissecting a Speaker video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

First, gently cut the paper speaker cone from the speaker basket (the metal frame) and lift the cone to show students what is inside. It will not come completely apart until you cut the spider (the ribbed ring of paper around the coil) from the basket.

Second, gently cut the spider from the speaker basket. The spider's main function is to hold the center voice coil in place.



*** Attending to Equity**
It is possible that some students may feel uncomfortable disassembling a perfectly good speaker. If this comes up, be sensitive to students' discomfort. Consider reusing one speaker across classes so that it feels less wasteful, or clarifying that this speaker is no longer useful. You can play the Dissecting a Speaker video instead, but this may be less engaging to students. The most important purpose of this activity is to let students see inside the speaker to identify the important parts.

Lift the spider and voice coil from inside the speaker. Allow students time to make observations of the tiny coil of wire.

Using a metal tool, like a screwdriver, tap on the center magnet in the speaker basket. It's difficult to remove the magnet and sufficient to show students that it is a magnet without removing it. Your screwdriver should stick to the magnet, which is a good way to show students the magnet.

Consider why the parts of the system help us figure out how it works. Briefly ask, *why are we identifying the parts of the system? What are some other times that examining the structure of a system helps us figure out how the system functions?* Accept 2-3 student responses and move on. Students might suggest scenarios such as:

- dissection in biology
- a doctor taking an X-ray to diagnose an illness
- a mechanic taking apart a car to identify a car issue*

Identify the parts of the speaker. Lay out the important parts of the speaker, including the coil of wire, the magnet-basket combination, and the paper speaker cone. As you identify each part, place by it an index card with the part name written on it. At this point, use language that comes from the class rather than imposing vocabulary that students will earn in the unit.

You may also consider labeling some of the other, less critical parts, such as

- the spider, which supports the speaker and helps keep its motion even (it stabilizes the movement), and
- the wires running to the speaker cone.

Now that students have identified three key parts inside the speaker (coil, magnet, cone), it's time to develop an initial model for how those parts work together to cause the speaker to vibrate.

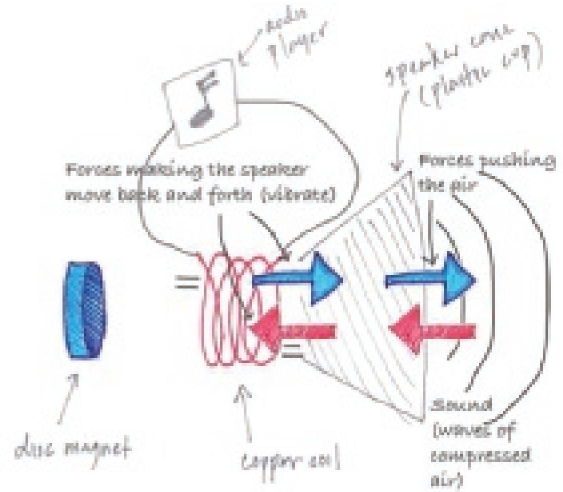
*** Supporting Students in Developing and Using Structure and Function**

Crosscutting concepts can be used to intentionally and explicitly make connections across science domains and other disciplines. Although structure and function are not foregrounded in this unit, take this opportunity to help students see that the structure of the system can help us figure out how it functions. This is also an opportunity to help students make connections across units. For example, you can encourage students to think about how looking at the parts of McKenna's digestive system helped us understand how it worked in Unit 7.3 "How do things inside our bodies work together to make us feel the way we do?" (Inside our Bodies).

3. Model the speaker system individually.
7 MIN

Materials: science notebook

Diagram the inside of a speaker. Remind students, *When scientists are trying to understand a phenomenon, they think of it and study it in terms of systems.** *They identify the important parts of the system and how those parts work together. This can give them clues about what to pay attention to and test. Let's think of our speaker as a system. We noticed several parts in the speaker that we thought were important, including the magnet* (point to the magnet)*, the coil of wire (*point to the coil)*, and the speaker cone* (point to the speaker cone).



Display **slide D**. Ask students to work on their own to draw a diagrammatic model of a working speaker system in their science notebooks. Emphasize the prompt at the bottom of **slide D**: *Show how the parts working together cause the speaker to vibrate.* Ask students to use annotations to show how they think the parts of the system interact to cause vibration.

As students diagram the system in their science notebooks, walk around the room and quietly ask probing questions, encouraging students to label their diagrams.

*** Supporting Students in Developing and Using Systems and System Models**

Systems and systems models are a focal crosscutting concept for this unit. A system is an organized group of related objects or components. Here we refer to those objects or components as parts. Scientists use models to understand and predict the behavior of systems. The first step in modeling a system in order to understand it is to figure out the important parts of the system. This allows scientists to study how the parts interact to produce the emergent behavior of the system as a whole. Help students set up their initial models as systems models by identifying the important parts of each system and thinking about how those parts work together (interact).

4. Identify the most important parts of the system.
13 MIN

Materials: science notebook, chart paper, markers

Share ideas with the whole class. Display **slide E**. Ask, *What parts did you include in your model?* As students share, record their ideas in a chart like the one below (and on **slide E**) at the front of the classroom. Ask, *Why did you decide that part was important to include?* Use questions to help students articulate their ideas clearly, but avoid correcting students.

As students share, probe their thinking about what each part does in the system. When students respond that they don't know, use that as an opportunity to help them articulate a question about that part of the speaker system. Ask, *What is it that we don't know? Let's record that question.* An example of what a finished table might look like is on the following page.

Part of the system	Why is it important?	Questions
Coil	It is metal, and it is connected to the music player.	Is there electricity in it? Is it attracted to the magnet?
Magnet	Magnets can push and pull on things without touching them.	Is it pushing or pulling on the coil?
Music player	The system doesn't work when it is off.	What is it sending in the wire?
Speaker cone	It makes a sound (we know there is a force on it and that it is vibrating in order to make the sound).	Why is it connected to the coil?
Spider	Maybe it holds something in place.	Could the speaker work without it?

Suggested prompts	Sample student responses
What does the magnet interact with?	*The magnet could be pulling on the coil.*
What is the coil interacting with?	*the music player/magnet/speaker cone*
You mentioned electricity moving through the wire. Why do you think electricity might be causing the forces that move the speaker?	*I know electricity makes things move. When I put a battery in a toy it makes the toy move.*

At this point, it is fine for students to list parts of the system that will turn out to be less important, such as the spider. Probe them on why they think these things are important and leave questions about their purpose in the last column of the table.

Summarize for the class. Depending on the time available, ask your students to summarize what they figured out so far from looking inside the speaker. If time is short, summarize for students by saying, *We now know what's inside the speaker. And we have some initial ideas about how these parts interact to make the speaker vibrate. We want to investigate more to figure out what parts are the most important and what they do.*

End of day 1

5. Navigation to the Homemade Speaker

10 MIN

Materials: preassembled homemade speaker, 4 small disk magnets, stereo audio auxiliary cable with both ends stripped, 1 pair alligator clips, music-playing device

Remind students why we are doing this. Say, *Last time, we identified the most important parts of a speaker. We decided that the magnet, the coil, and the speaker cone worked together somehow to produce forces that caused the sound. It turns out that with those three simple parts, we can actually make our own speakers. So I thought today we could try to build our own homemade speakers.*

Introduce the homemade speaker. Say, *I tried building one of these before class started.* Show students the main parts of the speaker and ask students if they notice similarities to the store-bought speaker (e.g., the cup is like the speaker cone, the wire at the base is like the coil of wire, and the magnet is like the magnet in the metal frame). Say, *I am going to give you all a chance to build speakers of your own, and then we can see if something this simple can actually make sound!*

Before sending students to groups, remind them why we are building the speaker. Display **slide F**. Say, *How do you think building a homemade speaker could give us more clues about what is producing the force or forces that cause speakers (in general) to vibrate?*

Listen for student responses like the following:

- When you build things, you can see how the parts fit together.
- We can figure out the most important parts inside the speaker.
- We might be able to see if the wire and magnet are connected.
- We could see where the electricity is going inside the speaker.

Preview instructions for building. To build the speakers students will follow a set of procedures, which are shown on **slide G** and included in the students' procedures book. Preview the procedures with students before they retrieve their materials. Use the demonstration speaker as you walk them through the steps of building their own speaker. Show students where they can test their speakers once they are built.

Ask if any students have questions before they get to work in their groups.

6. Building a Homemade Speaker

20 MIN

Materials: Building a Homemade Speaker, science notebook

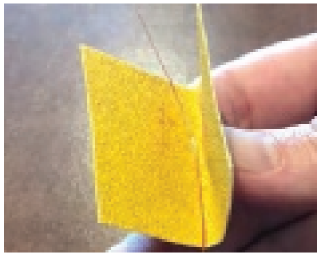
Prepare for the homemade speaker lab. Arrange students in groups of two or three. Have groups send one member to get the supplies. Consider having supplies arranged in a bin ahead of time to expedite materials distribution. Point out the sound testing stations. Setting up stations will allow groups to quickly test their speaker. Alternatively, if you provide one device to all groups for testing, make sure to prepare a sufficient number of audio cables connections for each group to connect their homemade cup speaker to the device.

Build and test the homemade speakers. Make sure **slide G** is still displayed. Give groups time to build and test their homemade speaker following the instructions below:

Wind the wire into a coil (around a ½- to 1-inch tube or a D-cell battery works well). Leave about 4 inches (10 cm) of wire at each end of the coil.

Wrap each end of the wire around your coil 2 times to hold the coil together. Leave at least 3 inches of wire free at each end.

Use the sandpaper to rub the enamel off the ends of the wire. You should see copper wire underneath.



Tape the coil to the bottom of your cup.

Attach the two free ends of wire on your cup speaker to the two alligator clips at the sound testing station. Put the magnets near the wire to see what happens.

As students test their speakers, ask them to move the disk magnets near and far away from the cup and wire. This will affect how loud the sound is coming from it. Let other students listen to the speaker.

Additional Guidance

As they build their speakers and you hear students saying they got it to work, ask questions about what they noticed and/or observed. After they describe what they noticed, follow up with probing questions about what is producing the force or forces that cause a speaker to vibrate. Ask questions like, *We know that in order to change the motion of something, you have to apply unbalanced forces to it. What is pushing or pulling on the thing that is vibrating and making sound? How close do the parts have to be in order for you to be able to detect sound coming from the speaker cone moving?*

Revise their initial models. Collect all the cup speakers from the groups. The cups and coils of wire will be reused in subsequent labs.

As each group finishes, have the students return to their seats to update their individual initial models in their notebooks until all groups have completed the lab. Display **slide H** with instructions on how to model the homemade speaker on the page to the right of their model of the store-bought speaker. Students should now title the full spread "Initial Models of a Speaker System." They should label the left page "Store-bought" and the right page "Homemade." As you walk around, remind students to focus on how the homemade cup speaker is similar to or different from the store-bought speaker. If some groups finish the cup speaker and revise their models very early, ask them to begin discussing their models in their groups, focusing on similarities and differences between the two speakers. Late finishers may not have time for a group conversation after revising their models.

7. Comparing Speakers

15 MIN

Materials: markers

Discuss similarities and differences in the speakers. Begin by reorienting students to where we are and why. Say, *We built our own speakers, and they worked! We want to use that investigation to help us understand how speakers work. Let's think about how the speakers that we built are similar to or different from the store-bought speakers that we were wondering about on the first day.*

Bring students' attention to the list of speaker parts that the class drafted on day 1 (see **slide E**). Ask students to share one observation (similarity or difference) they made comparing the parts of the store-bought speaker and the homemade cup speaker. Use a different colored marker to underline the parts that both speakers had in common and cross off the parts that the class decides are not important. Use the prompts below to focus students on thinking about how building the homemade cup speaker may have clarified for them the role of each part or raised more questions.

Part of the system	Why is it important?	Questions
Coil	It is metal, and it is connected to the music player	Is there electricity in it? Is it attracted to the magnet?
Magnet	Magnets can push and pull on things without touching them	Is it pushing or pulling on the coil?
Music player	The system doesn't work when it is off	What is it sending in the wire?
Speaker cone	It makes a sound (we know there is a force on it, and that it is vibrating in order to make the sound)	Why is it connected to the coil?
~~Sp[illegible]r~~	It is in the speaker, so it must be important. Maybe it holds something in place.	Could the speaker work without it?

Suggested prompts	Sample student responses
What was similar/different about the speaker cones?	*They are both open on one end. They both fan out.* *One was paper and the other plastic.*
What was similar/different about the magnets?	*Both magnets were round. When you moved them closer together, the music got louder.* *One magnet was stuck to the speaker basket and the other magnet could move close or far.*
What was similar/different about the coil of wire?	*both were coiled up* *The coil is smaller in the store speaker and bigger in the homemade speaker.*
Are there any parts that we listed as important that we don't think are important anymore?	*The spider (or paper around the coil) wasn't important because it wasn't part of the homemade speaker.*

Making sense of the speaker. After several students have had the opportunity to share their ideas, and some competing ideas have surfaced, conclude the discussion using the following prompts (show **slide I**):

- How did building the speaker help you understand the important parts of the system better?
- What questions came up for you as you built the speaker and compared it to the store-bought speaker?
- How do you think the magnet and wire work together without touching each other?

Summarize for students by saying, *It seems like we learned that speakers have to have a couple of key parts to work, like the magnet and the wire and the cone. We have some ideas about how the cup speaker worked, but we aren't sure. When a hand hits a drum, it puts a force on the drum and the drum puts a force on the hand. When a phone collides with the ground, the ground puts a force on the phone and the phone puts a force on the ground. Both of these are examples of contact forces. But in this case, the magnet doesn't have to be touching the wire to get it moving. We should investigate more how it could be possible for there to be forces between two things that aren't touching each other.*

Remind students to leave their science notebooks in the classroom so you can look at their models before the next class period.

Assessment Opportunity

Use students' initial models for a pre-assessment. If students are struggling to come to agreement on the important parts of the system (magnet, coil, speaker cone), spend time at the beginning of class on day 3 coming to consensus on the important parts of the system before considering interactions. Pick something that everyone in the class agrees is a system, for example, the solar system. Create a three-column chart with these column headings: "Important parts", "Not important parts", and "Not sure parts". Have students work together to decide the *important parts* of the system. Draw a sketch using these parts and the *not sure parts* but excluding the *not important parts*. The goal is for students to get more comfortable with figuring out which parts of the system need to be included in the model versus which parts are irrelevant. If most students are not modeling interactions, make note and push students to think more about the interactions (i.e., forces, energy, pushing, pulling) among the parts as the class develops a consensus model on day 3.

Are students modeling interactions or only drawing the speaker parts? Make note of the students who are representing interactions between parts, and bring attention to their representations as the class builds their initial models. Push students to think more about the interactions between the parts as the class develops a consensus model on day 3.

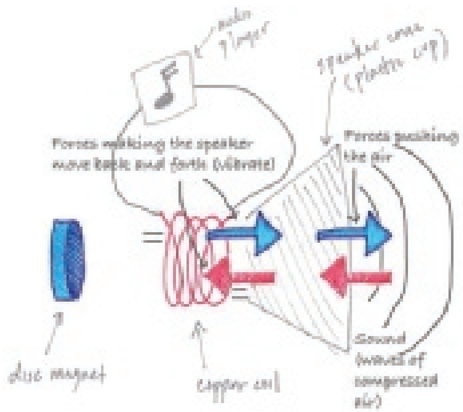
End of day 2

8. Develop an initial model for the speaker.

25 MIN

Materials: science notebook, chart paper, markers, Communicating in Scientific Ways handout, Initial Speaker System Model poster (developed in this lesson)

Gather in a Scientists Circle to develop an initial class model of the speaker system.* Remind students to bring their science notebooks containing their initial models. Begin by reminding students where we have been in order to set the stage for consensus. Say, *We dissected a store-bought speaker, and we built our own homemade speakers. Today we are going to develop a consensus model to explain how the important parts of the speaker system work together to make the speaker work.*



Take this opportunity to remind the class how we listen to one another, press on one another's ideas, and ask questions of one another and that it's OK to disagree with ideas but it's important to be respectful. You can use **slide J** to remind students of the classroom norms (if you have developed your own set of norms, replace this slide with your norms).

Remind students of the Communicating in Scientific Ways sentence starters.* Make certain a *Communicating in Scientific Ways* poster or handout is visible. Emphasize that each individual has contributions to make to their community of learners. Ask them which sentence starters they might want to use to help them talk to one another. Examples include these:

Think of an idea, claim, prediction, or model to explain your data and observations:

- My idea is ….
- I think that ….
- We could draw it this way … to show ....

Give evidence for your idea or claim:

- My evidence is ….
- The reason I think that is ….

Other examples could come from (1) listening to others' ideas and asking clarifying questions, (2) agreeing or disagreeing with others' ideas, and (3) adding onto others' ideas.

*** Supporting Students in Three-Dimensional Learning**

Over the course of this unit, students will engage several times in modeling (SEP) of a system (CCC) to explain how forces act at a distance (DCI). Their initial models may only include parts of the system and amorphous references to how they interact, but over time, they will begin to incorporate invisible cause and effect mechanisms (CCC) in the magnetic field (DCI). Because students have developed only their initial models so far, they may not be able to incorporate DCIs to explain the phenomenon with confidence yet, and that is OK. Models and explanations are supposed to change as our knowledge grows.

Additional Guidance

Establishing norms is an important focus early in the school year. The brief reminder about norms that happens in this moment assumes that your classroom norms have already been established in a previous unit. For more information about norms and how to establish them in your classroom, refer to the *Teacher Handbook*.

Present **slide K** to review the purpose of a Consensus Discussion. Tell students that the goal of this discussion is to determine areas of agreement and disagreement in our initial models to help us decide how to proceed in figuring out how the speaker works.

Scientists Circle

Your students may be familiar with the Scientists Circle from the previous unit. Remind students of the norms for participation and the logistics for forming and breaking down that space. A Scientists Circle includes these important features:

- students sitting so they face one another to build a sense of shared mission and a community of learners working together
- celebrating progress toward answering students' questions and developing more complete explanations of phenomena
- focusing on where students need to go next and how they might go about the next steps in their work

The class will be in a Scientists Circle all day today, so you will not need to change the arrangement of chairs between classes.

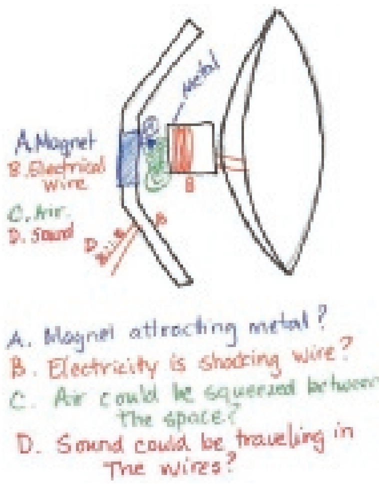
Initial sharing of models. Pick three students with different models to come up and show their models to the class. Try to pick examples that show different ideas and mechanisms than the others. When students share, they should explain all the elements in their models. Use probing questions to get them to articulate each piece of the model. After each presentation, ask students to look at their own model and the one that was just presented to find similarities and differences between them. If something is repeated in multiple models, emphasize that to the class or ask students to share what was common across the shared models. When all three presentations are done, transition to developing a class consensus model.

Create an initial model. Prepare to draw a sketch of the speaker system on chart paper that has been titled "Initial Speaker System Model." Point students to the list the class made of important parts of the speaker (see **slide E**) to help decide which parts of the system to include (e.g., magnet, coil of wire, speaker cone). Remind students, *When we are identifying important parts of the system, let's ask ourselves what would happen if the part were not there. Would it change the outcome? If so, the part is probably important.**

To document the class's initial ideas, have students focus first on the similarities in their models. As students come to agreement on parts of the model, draw a diagrammatic model to represent everything that students agree upon (e.g., the parts of the model, where they are located in relation to one another, whether the magnet and coil of wire need to be close but not touching, electricity going to the speaker, and so forth). There may be very little at this point that students agree upon.

*** Strategies for This Consensus Discussion**
In a Consensus Discussion, it is important to accept all student responses and to encourage students to share their ideas. Help students to articulate their ideas clearly in order to highlight areas of disagreement and areas of agreement. Be careful not to favorably respond to any one idea over others so as not to "give away" what might be going on in the speaker.

*** Attending to Equity**
You may use color coding to foreground parts of the model. Although color coding is a useful way to quickly reference the parts of the model, letter or number coding helps ensure accessibility for any student who may be color-blind. Create a key to track what colors, symbols, numbers, or letters represent different parts of the system.



Key Ideas

Purpose of the discussion: There are two goals of this discussion: (1) to continue to help students build the habit of sharing their ideas publicly and (2) to generate a variety of initial ideas about what is going on in the speaker that students agree with, disagree with, or are uncertain about.

Listen for these ideas:

- Important parts of the system are the magnet, the coil of wire, the speaker cone, and what the coil of the wire is hooked up to (the electronic music player).
- There is a force on the speaker cone that is making it move, and we think that the force has something to do with the magnet.
- There may be something going on in the space between the coil of wire and the magnet, but we aren't sure.

Record the initial consensus model in students' progress trackers. Ask students to turn to the first page of their Progress Trackers, and make a line about a third of the way across the page. Students should record the lesson question on the left side of the line. On the right side, ask them to record an initial model for the speaker.

9 · Broadening to Related Phenomena 12 MIN

Materials: science notebook, chart paper, markers, Related Phenomena poster (developed in this lesson)

Stay in a Scientists Circle to identify related phenomena. Prompt students to think about examples of other objects that they suspect use magnets and/or wire to make the object or some part(s) of the object move. Present **slide L**. Ask, *Where else have we seen these same kinds of parts in a different system making something move?*

Have students turn and talk about their ideas before sharing out with the whole group. Accept all student responses. Record students' ideas on chart paper using a table like the one shown below. If you haven't already, title the poster "Related Phenomena." If students note objects that use both magnets and wires together, ask them to think about how the two work together to help make the object or part of the object move (e.g., metal detector, earbuds, sprinklers, pinball machine, scrapyard magnet).*

What is the system? Which parts move?	How does it move?	Are the parts of the system touching?

Conclude the discussion by saying, *It seems like either magnets or wires or a combination of both together can produce a force or forces that can make things move. If we can figure out what the magnets and wire are doing in the speaker, we might be able to figure out how they can be used in other systems to move things too.*

*** Attending to Equity**

Use talk strategies to draw out a wide variety of related phenomena from a larger pool of students.

- If it feels like students don't have any more ideas, don't move on right away. Instead, count to ten in your head to give students more time to consider.
- Have students jot down some ideas in their notebooks after their partner talk and before sharing out. This can be particularly supportive for emergent multilingual students.
- Use questions to push students' thinking to new contexts and provide more opportunities for students to make connections to their experiences. For example, if students are only naming kitchen appliances, say, *It seems like most of our examples are pretty small. Can anybody think of something that uses magnets or electricity to make something really big move?*

10. Navigation

8 MIN

Materials: science notebook

Look at a close-up photograph of a store-bought speaker. Say, *We could get the homemade speaker to vibrate even when the magnet was not touching the coil. Do you think the magnet and the wire in the store-bought speaker are touching or do you think there is a space between them as well?* Take a show of hands.

Additional Guidance

After the consensus modeling activity it should be clear to most students that there does not need to be contact between the wire and magnet for the speaker to vibrate. In fact, as students will learn later in the unit, lack of contact reduces friction and increases the efficiency of the device. However, not all students may be convinced that the wire and the magnet are not actually touching. In the store-bought speaker, disentangling the parts to see the space can be a challenge. This navigation activity establishes that there is air between the magnet and wire and that the force is acting across this space.

Say, *I have a close-up photograph of our store-bought speaker. If we look more closely, we might be able to figure this out*. Present **slide M** and ask students to examine the photograph and discuss whether there could be a gap between the magnet and coil, even if it's a small one. Give students about a minute to discuss with a partner.

Elicit ideas from several students. Ask students to share what they discussed with their partner.

Listen for student ideas like the following:

- We think there could be a little gap between the two.
- There is some space but not as much as in the cup speaker.
- The thickness of the coil seems to be a little less than the thickness of the space.

Introduce the unit question. Display **slide N**. Now that students have established there is likely space between the magnet and coil, ask them, *How can a magnet move another object without touching it?*

Listen for student ideas reaffirming that it could be magnetic, electrical, vibrations, or related to air particles. These are ideas from previous grades and previous units that they will likely try to use at first to explain this new phenomenon, and that is OK.

Have students record the unit question where they reserved space on the title page for this unit in their notebooks.

End of day 3

11. Develop questions for the Driving Question Board. 15 MIN

Materials: sticky notes, markers, chart paper, Initial Speaker System Model poster (developed in this lesson), Related Phenomena poster (developed in this lesson)

Reorient to the unit question. Display **slide N**. Say, *Last class we wrote down our unit question. What do we need to know in order to answer this question?* Have students turn and talk with their partners or in small table groups to brainstorm for two minutes.

Say, *Today we will create our Driving Question Board and brainstorm some ideas for investigations that we can do in order to figure this out.*

Write initial questions for the DQB. Make sure the Related Phenomena poster and the class's Initial Speaker System Model are posted at the front of the room where students can see them. Display **slide O**. Then pass out 3-4 sticky notes and a marker to each student. Ask students to write one or two questions on the notes about the speaker system, a part of the speaker system, or related phenomena. They should record only one question per note. They should write their questions big and bold—we want to be able to see the questions clearly.

Establish a shared understanding of cause and effect. Say, *When scientists ask questions about a system, they are usually looking to identify cause-and-effect relationships. Let's think about the speaker system in terms of possible cause-and-effect relationships that we might want to know more about.**

Display **slide P**. Say, *Before we begin brainstorming, let's come up with a shared understanding of what a cause-and-effect relationship is. A cause-and-effect relationship describes what happens to a system when you change it. It can usually be described with a statement that sounds like this: "When we change this, then we observe that."*

- *When I drop my phone on a hard surface, then I observe the screen shatter.*
- *When I turn the key in the classroom door, then I observe the lock open.*

Turn to a partner and share an example of a cause-and-effect relationship in your everyday life using an "when this, we will observe that" statement.

After students share with their partner, solicit 2-3 student ideas quickly, then display **slide Q**. Ask, *Is there a cause-effect statement that we can definitely make about the speaker right now? Is there a change that we could make to the system where we know for sure what we will observe if we make that change? Turn to your partner and discuss for a minute, then write down at least one example in your notebooks under the title "Cause-and-Effect Observations."*

After about two minutes, solicit 2-3 student ideas for cause-effect statements about the speaker. Look for students to suggest things like these:

- When we turn off the music player, we observe that the music stops.
- When we move the magnet away, we observe that the music stops.
- When we move the magnet closer to the coil, we observe that the music gets louder.

Record these statements at the front of the room (e.g., on chart paper). After writing each student example, pause to point out the cause, or change to the system (e.g., turning off the music player), and the effect we observe (e.g., the music stops).

* Supporting Students in Developing and Using Cause and Effect

Cause and effect is a focal crosscutting concept for this unit. Revealing causal relationships and the mechanisms that connect cause to effect is a major activity of science and engineering. The fill-in-the-blank scaffold introduced here will eventually become a table that students use to organize their thinking about the interactions in a system. They will come back to this table frequently. In Lessons 10 and 11, this cause-effect scaffold will support students in determining independent and dependent variables and writing investigable questions to determine the nature of the relationship between these variables.

* Supporting Students in Engaging in Asking Questions and Defining Problems

Asking questions is a focal practice in this unit. In middle school, the NGSS specifies that as part of the development of this practice, students are expected to "frame a hypothesis based on observations and scientific principles" but only "when appropriate." These words are chosen carefully, because asking questions, making predictions, and framing hypotheses are not the same thing. It is important to note the distinction between the types of predictions and questions students have been making up

Display **slide R**. Say, *There are a lot of ways that scientists ask questions about cause-and-effect relationships in systems. We could ask a question about the effect. We could ask a question about the change we need to make to get the effect. We could also ask a how or why question about a cause-and-effect relationship we are pretty sure about. Can anybody take one of these statements at the front of the room and explain <u>why</u> the change we made to the system causes the effect? Turn to a partner and discuss.**

Give students a couple of minutes to discuss. Meanwhile, walk around the room, using probing questions to help clarify student ideas to reveal gaps in their understanding. For example, if a student says that the music stops when the magnet is removed because the magnet is pulling on the coil and causing the vibration of the speaker, challenge the student to explain the mechanism or push them for evidence. The goal of the exercise is to reveal how little we know about the mechanisms underlying these cause-and-effect relationships.

Bring the class back together and display **slide S**. Say, *I've added the word <u>because</u> to our cause-effect sentence for when we have an explanation that connects cause and effect. It seems like we still have a lot of questions about how and why these changes to the system cause these effects. We can describe cause-and-effect relationships that we observe or predict using just "if" and "then", but as we dive deeper into our investigations, I hope we will also start to fill in some becauses.*

Write questions for the DQB based on cause and effect.* Point to the examples on the slide. Say, *Here are some question frames that we can use to ask about cause and effect.*

1. What is the effect when we make this change?
2. What is the change we would need to make to get this effect? What part(s) of the system is involved in this change?
3. Does this change cause this effect?
4. How or why does this change cause this effect?

Pass out another one or two sticky notes to each student.* Ask students to write one or two new questions on the notes, one question per note, using the cause-effect framework to reveal what we don't know and want to know more about.

Assessment Opportunity

Cause and effect will serve several purposes throughout this unit to organize student thinking about the DCIs and to scaffold the development of practices. In this lesson, students use cause and effect to think about interactions between the parts of the system in order to scaffold the practice of asking questions. If students are still having trouble translating the cause-effect framework into questions for the DQB, consider spending some time with more familiar systems, for example, dropping a pencil. Ask students to rewrite the question frames on the slide for this example:

- *What is the effect I will observe when I let go of the pencil?*
- *What is the change we would need to make to get the pencil to fall?*
- *Does letting go of the pencil cause it to fall?*
- *How or why does letting go of the pencil cause it to fall?*

Then ask students to write a cause-effect sentence for this system.

- *When I let go of the pencil, I will observe it falling down because I am not holding it anymore, so I am not stopping gravity from pulling it down.*

until now, and the hypotheses they will write in this unit, starting in Lesson 3. According to Appendix H of the NGSS, a hypothesis is an "idea that may contribute important new knowledge for the evaluation of a scientific theory" (p. 5). It is not simply the articulation of a pattern, but rather the articulation of a pattern that if established, would lend support to a mechanistic model/explanation for a phenomenon.

* Supporting Students in Three-Dimensional Learning

The cause-effect scaffold is used in several ways across this unit. Each version of the scaffold has slightly different sentence structure and syntax:

- Students use "when we...we observe…" syntax to describe cause-and-effect relationships very generally and to support the development of <u>questions</u> about cause-and-effect relationships (e.g. this lesson).
- Students use "when we….
we will observe…" to make <u>predictions</u> (e.g. lesson 2).
- Students frame <u>hypotheses</u> using the frame "if . . . .then when we…..we will observe…", which includes not only an observable cause-effect pattern but also the mechanistic explanation that we hope to uncover through an investigation that establishes the pattern (e.g. lesson 3).

12 · Develop the Driving Question Board. 15 MIN

Materials: science notebook, sticky notes with questions written on them, DQB (developed in this lesson), Initial Speaker System Model poster (developed in this lesson), Related Phenomena poster (developed in this lesson)

Gather in a Scientists Circle around the DQB. Instruct students to bring their sticky notes with completed questions along with their science notebooks to meet in a Scientists Circle around the DQB. Remember that the backdrop of the DQB could be the class's Initial Speaker System Model; if not, the Initial Speaker System Model should be posted nearby and a space, such as a bulletin board, can be used for the DQB. Post the Related Phenomena poster next to the Initial Speaker System Model.

Additional Guidance

The Driving Question Board will be central to the sensemaking that happens in the unit. There are a variety of ways to set up the DQB depending on your classroom resources, use of technology, and the number of students you see each day. What works for some will not work for others. Most important is that the DQB is visible to students each day and represents "our shared mission". Students will be using the DQB to assess what they've figured out and identify next steps.

Remind students how to create the DQB (use **slide T** if needed):

- The first student reads their question aloud to the class then posts it on the DQB near the part of the initial consensus model the question most relates to or on the Related Phenomenon poster.
- Students should raise their hand if one of their questions relates to the question that was just read aloud.
- The first student selects the next student whose hand is raised.
- The second student reads their question, says why or how it relates, and posts it near the question it most relates to on the DQB.
- The student selects the next student, who may have a related question or a new question.
- We will continue until everyone has at least one question on the DQB.

Organize questions into categories. As students share, questions will naturally cluster into similar areas of the model, such as questions about the magnet and questions about the coil. If you are using the Initial Speaker System Model as the backdrop for the DQB, ask students to post questions about specific parts of the system near that part of the consensus model. Once students have finished their sharing, ask students to look at the questions for any additional organization that can be done.*

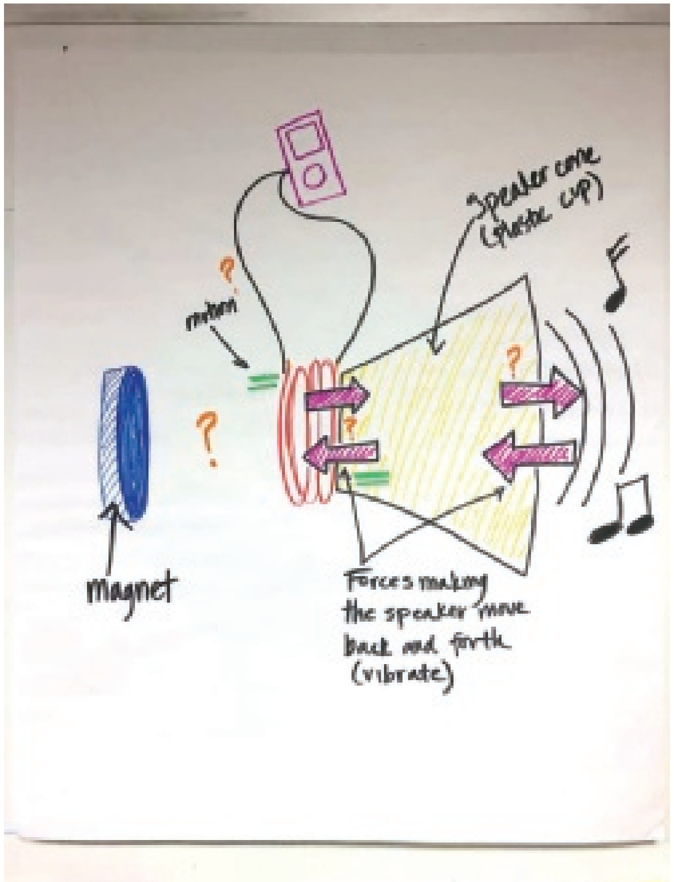
Additional Guidance

As the class builds the Driving Question Board (DQB), listen for (1) the kinds of open-ended questions being asked and (2) how the questions relate to the systems model. It is important that *all* questions posed by students be placed on the DQB regardless of whether they are open-ended or close-ended. Make note of any close-ended questions and use navigation time throughout the unit to turn them into open-ended questions when they relate to the investigations underway.

See *Using Cause-Effect Scaffolds to Support Science and Engineering Practices* for more detail on how these sentence frames are used across the unit to support student sense-making and engagement in the science and engineering practices.

*** Supporting Students in Engaging in Asking Questions and Defining Problems**

The purpose of this activity is to support students in asking questions about phenomena that will lead to investigations by making connections to the crosscutting concept of cause and effect. These should be questions that (1) we can answer through investigation and (2) will help us explain how these things work the way they do. Tell students that they can rewrite their old questions right now or come up with a new question. Remind them that there are many valuable questions that we can come up with that don't fit the cause-effect framework, and that is fine too.



*** Supporting Students in Developing and Using Systems and System Models**
Systems and systems thinking is a focal crosscutting concept in this unit. As students ask questions, have them reflect on any parts of the speaker system (or related systems) that have few or no questions posted on the DQB. Prompt students to generate more questions in this space so that each important part of the system is to be investigated.

13. Plan ideas for investigations.

13 MIN

Materials: chart paper, markers, Ideas for Investigations poster (developed in this lesson)

Stay in a Scientists Circle to brainstorm further investigations. Display **slide U**. Ask, *How can we investigate some of these cause-and-effect relationships we asked questions about, and what else can we do to figure out how this system works?* Have students turn and talk to a partner about ideas for future investigations to pursue. They could write these ideas in their science notebook or, if time is short, they could spend a minute generating a couple of ideas aloud with their partner.

Then ask students to share their ideas with the whole group while you record on chart paper a list of these ideas for investigations. This Ideas for Investigations poster will remain public throughout the unit.

To ensure all students share their ideas, say, *To make sure we have everyone's ideas up here, I will pass a marker to the first person on the edge of the circle. The student with the marker should share one of their ideas. I will write it up here and* *number it. That student should pass the marker to the student next to them. The second student then shares an idea and so on. If a similar idea is on the poster already, the student should say which idea it is and how it is similar. I will then put a tally mark next to that idea.*

The marker is passed all around the circle and all students have a chance to have their thinking represented on this poster. Offer to students that if they have additional ideas that don't end up on the poster, they may raise their hand after we have heard once from everyone in the class (after the marker goes all the way around the circle) to share those ideas. Emphasize to students that the Ideas for Investigations poster can change throughout the unit as they learn more. If students think of new ideas along the way, ask them to jot them down in their notebook to add to the poster later.

14. Navigation

2 MIN

Materials: None

Decide where to go next. In this last activity in Lesson 1, it is important to remind students of the mission of the class and to motivate a series of investigations. Remind students that the mission of the class is to figure out how the parts of the speaker system work together to cause the vibration that creates the sound. Say, *We have accomplished so much. We now have a better idea about which parts of these systems could be really important for explaining what is happening, and you've come up with good questions for us to investigate. I am very excited for us to get started on investigating all of this. It seems like we are interested in the relationship between the magnet and the coil and figuring out what magnets push and pull on. In our next lesson, we can spend some time making observations of magnets and coils to find out more.*

Additional Guidance

Remind students to keep their science notebooks organized by writing a title on each page and updating their table of contents. They can do this when they have extra time at the beginning or end of class or during homeroom or homework time.

ADDITIONAL LESSON 1 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-Literacy.SL.6.1.c: Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

When the class is building the Driving Question Board, if a student forgets to explain why or how their question is linked to someone else's question, press that student to try to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off one another's ideas and to help scaffold student thinking.

Don't worry if some questions are raised that do not lead to productive investigations. Over time students will get better and better at forming testable questions in the scope of the driving question. This type of activity gives them practice at doing that.

If students can't figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.

Today's activities rely on students communicating and articulating their thinking. One tool that may support classroom discussion is the Communicating in Scientific Ways sentence starters. This 1-page document can be blown up and printed as a class poster, printed on 8.5-×-11 paper and posted near students' desks, and/or scaled down and taped into students' science notebooks. To support discussion, reference the sentence starters on the poster and encourage students to use those sentence starters to help them communicate. The sentence starters can be especially useful for helping students engage in scientific talk, particularly students who may feel reluctant to contribute.

LESSON 2

What can a magnet pull or push without touching?

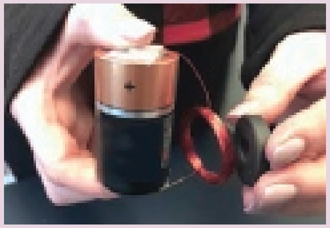
Previous Lesson

We made observations of a dissected speaker and built a homemade speaker to identify the important parts that work together to cause the speaker to vibrate. We developed an initial model for the speaker system and generated questions to develop our Driving Question Board (DQB) using a cause-effect scaffold.

This Lesson

Investigation

2 DAYS



We experiment with several objects to establish that while certain metals do interact with magnets, including other magnets, the copper coil does not. We realize that there is a force on the magnet and a force on the coil only when the coil is connected to a battery. We figure out that we can change the direction of these forces from attractive to repulsive by changing the orientation of either the magnet or the coil of wire.

Next Lesson

As a class, we will carry out investigations to collect evidence to either support or disprove the model idea that air transfers energy between magnets.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Collect data to establish that magnets interact with certain objects to cause paired forces that are either attractive (both pulls) or repulsive (both pushes) and that changing the orientation of either of the magnets will cause both forces to reverse direction.

Collect data to answer questions about the coil of wire and provide evidence to support the claim that connecting the coil of wire to a battery causes the same paired forces between the coil and a magnet as between two magnets.

What Students Will Figure Out

- Some metals are pulled by magnets (like iron), and some are not (like copper).
- Whenever there is a force (a push or a pull) on one of the magnets, there is also the same kind of force on the other magnet.
- When both magnets are pushing, the two are repelled (move away from each other), and when they are both pulling, the two are attracted (move toward each other).
- In a system with two magnets, we can get them to switch the type of force they are producing (attractive vs. repulsive) if we flip the orientation of one of the magnets.

- There are forces between the magnet and the coil when the coil is connected to the battery.
- Just like in a system with two magnets, we can get both pushes and pulls (repulsive and attractive forces) between the magnet and the connected coil.
- Just like in a system with two magnets, we can get the connected coil and the magnet to switch the type of force they are producing (attractive vs. repulsive) if we flip the orientation of either one of them.
- When the connected coil or magnet move, they have kinetic energy.

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Students share ideas about how the magnet could be responsible for pushing and pulling something in the speaker.	A-B	
2	15 min	**INVESTIGATING MAGNETS** Students test magnets with a bunch of different materials, such as coins, paper clips, nails, copper wire, and compasses, to determine which combinations produce pulls and if any material produces a push and a pull.	C-D	Magnet interactions investigation
3	15 min	**BUILDING UNDERSTANDINGS** Hold a Building Understandings Discussion to develop some important ideas about magnets and add them to the Progress Tracker in students' science notebooks.	D-H	*Magnet interactions lab*, *Composition of Metal Objects*
4	5 min	**NAVIGATION - EXIT TICKET** Motivate the next activity by highlighting what we don't know about the copper coil with an exit ticket.	I	scraps of paper for exit ticket
				End of day 1
5	5 min	**NAVIGATION: MAKING PREDICTIONS**	J-K	
6	20 min	**CONNECT THE COIL OF WIRE TO A BATTERY** Students connect a copper wire coil to a battery to produce a current in the wire. They observe the coil moving when they place a magnet nearby, indicating that the coil is now being either pushed or pulled by the magnet.	L-O	chart paper, markers, Magnet and coil interactions investigation
7	10 min	**BUILDING UNDERSTANDINGS** Hold a Building Understandings Discussion.	O-P	magnet

Part	Duration	Summary	Slide	Materials
8	10 min	**NAVIGATION** Navigate to the next lesson by reminding students that energy must be transferred to get the system parts to move and then collecting an exit ticket.	Q-R	
				End of day 2
		SCIENCE LITERACY ROUTINE		Student Reader Collection 1: *Day-to-Day Magnets*

Lesson 2 • Materials List

	per student	per group	per class
Magnet interactions investigation materials	• science notebook • *Magnet interactions lab* • *Composition of Metal Objects*	• 1 coil of wire from the homemade speaker • 2 small disc magnets • 1 paper clip • 1 quarter • 1 penny • 1 iron nail • 1 compass • 1 square inch of aluminum foil • plastic cup from the speaker model (optional)	
Magnet and coil interactions investigation materials	• *Magnet and coil interactions investigation*	• coil of wire from the homemade speaker • 1 small disc magnet • D cell battery • tape • small stickers	
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Magnet interactions lab* • scraps of paper for exit ticket	• *Composition of Metal Objects*	• chart paper • markers • magnet

Materials preparation (30-45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1: How do magnets interact with other materials?

- **Group size:** Prepare materials for groups of 3-5 students.
- **Setup:** Students will need access to their homemade speakers to remove the coil and the magnet for additional investigations. Students will need to store their coil and magnet to be reused between lessons, so they can place the coil and magnet inside their speaker cup for storage.

Day 2: What is the effect on the coil and the magnet when we connect the coil of wire to a battery?

- **Group size:** Prepare materials for groups of 3-5 students.
- **Setup:** Gather materials for lab and ensure that batteries are not dead.
- **Notes for during the lab:** The batteries should last from class to class, but if they have been used for several periods in a row, consider testing them to make sure they are not dead.
- **Safety:** Never plug the coil into an outlet. Only connect the wires to a D cell battery (provided). Be aware that if left connected to the battery, the coil will become hot to the touch and drain the battery. Tell students to disconnect the wires from the battery when they are not testing their system. Be sure that all wires are disconnected from the batteries when you put the supplies away at the end of class. Do not store the batteries in the same container as the coils or the magnets.
- **Disposal:** Dispose of dead batteries responsibly. Check with your school about battery disposal. If you must dispose of batteries in the trash, first secure a piece of tape over each terminal end of every battery or place each individual battery in a strong, plastic, zip-top bag before placing in the trash.

Online Resources

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In the previous unit, *Unit 8.2 How does a sound make something vibrate?* (*Sound*), students reviewed and built on the ideas that sound can make matter vibrate and vibrating matter can make sound (1-PS4.A). In *Unit 8.1 Why do things sometimes get damaged when they hit each other?* (*Broken Things*) they reviewed and built on the idea that each force acts on one particular object and has both a strength and a direction (3-PS2.A). What they may not remember from previous grades is that electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact and that the strength of the forces between two magnets depends on their orientation relative to each other (3-PS2.B). Be prepared to reinforce this idea.

In grade 8, students should begin thinking about forces in terms of two interacting objects with equal and opposite forces acting on each (Newton's third law). This lesson frames forces as pushes and pulls between a magnet and another object (rather than the magnet acting on another object).

Students figure out that magnetic forces can be attractive or repulsive (from 8-PS2.B) in this lesson. While this idea is also developed in earlier grades, this lesson reviews the idea by asking students to experiment with whether pushes and pulls are produced when two different objects are brought near each other (different magnets and metal objects).

Students will develop the idea that magnetic forces exist between magnets and other magnets and between magnets and certain metals but that not all metals interact with a magnet to produce repulsive or attractive forces without touching each other. Some students will have experience with magnets and may believe that all metals will be attracted to and/or will attract a magnet. They may apply these experiences to predict that the magnet will pull on the copper wire (and/or vice versa), regardless of whether the wire is connected to anything. These students will be surprised to see that the copper coil does not interact with the magnet. This will lead students to wonder about what can be done to the copper coil of wire to cause it to produce attractive or repulsive forces, which will lead to the creation of an *electromagnet* (students will earn this word in Lesson 3).

Where We Are NOT Going

Though Newton's third law is not addressed explicitly in this lesson, students will find evidence of two objects in a system both being pulled together or both being pushed apart. They will establish that there are two forces working in opposite directions on these objects, which is an important idea to developing and applying Newton's third law, but determining whether those forces are equal in strength is not part of the core learning activities in this unit. Students will have established the idea of equal and opposite forces on two objects in contact with each other in the *Broken Things* unit. If you feel that students need to review the existence of equal and opposite force pairs before this lesson, consider doing so in the context of contact forces.

Some students may think that nonmetals can be attracted to and/or will attract a magnet since they may have seen magnets with a plastic or rubber coating (e.g., refrigerator magnets). If this is the case, introduce the plastic cup from the homemade speaker either as a demonstration or as an object to test in the lab in order to eliminate this possibility.

Students may use principles from what they learned about sound propagation in the *Sound* unit and from their own experience to explain what is happening between the magnet and the wire and cup by invoking air compression or air particle collisions as a mechanism to transfer force. Students may explain that the force is being transferred through particle collisions in the air or that the magnet simply pushes or compresses the air, which then pushes the coil and cup. This is a productive line of reasoning that we will investigate in Lesson 3, so do not correct this idea yet.

Students will see that the coil of wire acts like a magnet when it is connected to a battery. They may not yet think of the coil as magnetic, but they will begin to notice that the patterns they see in a magnet are also seen in the coil as an effect of the battery. But they will not dig deeper into what this means until Lesson 8. Do not comment on students' use of vocabulary like "electricity," "current," or "electrical force" at this point. These ideas will be developed later. Right now, focus on the cause-effect relationship rather than the mechanistic explanation: When we connect the wire to a battery, then the wire acts like a magnet.

1. Navigation

10 MIN

Materials: science notebook

Revoice the idea that sound is the result of vibrations. Say, *In the last lesson, we made a homemade speaker from a magnet, a coil of wire, and a cup. The speaker made a sound, so it must have been vibrating. Something has to push and pull on the speaker to get it to vibrate at different frequencies and amplitudes to produce different sounds.**

Share what we know about magnets. Display **slide A**. *We suspected that the magnet was pushing and pulling on something. Why? What do we already know about what magnets can push and pull on? Share your ideas with the whole class.**

Suggested prompts	Sample student responses	Follow-up questions
What have you seen before that makes you think that a magnet can push or pull something?	*A refrigerator magnet sticks to certain surfaces. A paper clip sticks to a magnet. Magnets stick to each other.*	*Is the magnet being pulled toward that thing or being pushed away from it?*
When a magnet sticks to your refrigerator, does it get pulled or pushed?	*It's a pull.*	*Does everyone agree with _____ that the magnet is pulled toward the refrigerator?*
Have you ever seen something else pull a magnet?	*Accept all examples.*	*Interesting. So in some cases maybe the magnet is getting pulled toward something else, and in other cases maybe something else is getting pulled toward the magnet. Do you have any experiences where you think both might have been happening?*
Have you ever seen a magnet push something or get pushed by another thing, or do they just pull things?	*Magnets can push each other away.*	*So was only one thing pushing on the other thing, or were they both pushing on each other? How could you tell?*
*It sounds like we think that magnets and some other things may pull on each other, and in some cases maybe they can push. Do the magnets have to touch for them to get pushed or pulled by something else and/or push and pull on that other thing?**	*No, they can do it without touching.*	

*** Supporting Students in Developing and Using Systems and System Models**

Remind students that the diagram of the speaker represents a system, which is a group of related parts that interact in ways that allow the entire whole to carry out a function that individual parts cannot. The magnet, the coil, the electronic music player, and the speaker cone are all parts of the system. Our goal is to figure out how these parts work together to produce sounds, which is the function of the system.

*** Attending to Equity**

Draw on students' experiences with magnets to help them see why this content is relevant to them. Consider asking students to each bring in a magnet from their own refrigerator or locker to test in this investigation and/or to have available for future investigations. Would one of those magnets also make the speaker work? If there is time, try it.

If students bring in magnets, give some space for them to share the magnet with the class and where it came from. Is it from a family trip? Is it sent from a relative who lives elsewhere? Is it an advertisement from a local company? Is it a picture of a loved one? Use these examples to

Additional Guidance

Continue to encourage students to use both everyday and scientific vocabulary by asking questions to probe their ideas. For example, if a student says that something sticks to a magnet or is attracted to a magnet, ask the student, *Are you saying that the object is being pulled toward the magnet or the object is being pushed away from it?* Consider using hand gestures to mime a push and pull. This is particularly important for emergent multilingual students, but will benefit all students. Later in the lesson, we will begin to use the words *force*, *attraction*, and *repulsion* more consistently, but it is important for students to spend some time thinking about these forces using a hybrid of everyday and scientific language that will help them make conceptual connections between science and their experiences.

Elicit student predictions about what will happen when the magnet gets close to the wire. Display **slide B**. Ask students to turn and talk about the question, "What do you predict will happen when we put the magnet up close to the metal wire without letting it touch?" Probe students to clarify their ideas and to justify their predictions. Highlight any areas of controversy around what will happen.

Stop and jot our initial ideas about what a magnet can push and pull without touching. Say, *We have a lot of experience with magnets and a lot of ideas about what a magnet can push and pull without touching. That is our lesson question for today: What can a magnet push or pull without touching?* Write this question on the board. Ask students to record this question in their notebooks on a new page. Beneath the question, they should record some of their initial ideas in a brief, individual Stop and Jot activity.

Say, *Let's investigate and get some scientific evidence to support our ideas.*

Additional Guidance

Walk around the classroom to get a sense of what students are writing. If students are not convinced that magnets only interact with metals, consider including the plastic cup and/or the speaker cone as a testable material in the lab to come.

highlight how common magnets are in our lives across a variety of contexts, even when we don't notice them. If you have concerns about students bringing in their own magnets, consider bringing in some of your own magnets to test in the investigation and/or with the homemade speaker. This may get students thinking about the magnets they have seen at home without requiring them to compare what they have.

*** Strategies for This Initial Ideas Discussion**

As students make suggestions, press them for reasoning by asking, *What makes you think that?* Do not attempt to guide students toward an answer, but highlight ideas they raise about experiences they have had with magnets that lead them to believe that a magnet can push or pull on certain things.

2. Investigating Magnets

15 MIN

Materials: Magnet interactions investigation

Say, *I've got a lot of different objects here that we can use to figure out what a magnet can push and pull on without touching, including the copper wire. As you test an object in your group, make sure that you record your observations in the table on the student handout.*

Conduct the investigation in small groups. Form groups of 3-5 students. Display **slide C** and pass out a copy of *Magnet interactions lab* to each student. Students should record the investigation question (What can a magnet pull or push without touching?) in their notebooks and then insert the handout. Tell students to follow the directions on the slide and in the handout. Show students the materials that you have set up and tell them that each group should pick up only one of each. Consider using bins to keep the materials organized. When students are finished with the investigation, switch to **slide D** while students work on the discussion questions in their groups.*

- Which materials (if any) produced both attraction (pulls) and repulsion (pushes) with the magnet?
- For those materials that produced both attraction and repulsion, how did you get the forces to switch from pushes to pulls and back again?

*** Supporting Students in Developing and Using Patterns**

This lab requires students to look for patterns in their data that they can use to figure out something about magnets and their interactions. As you walk around the classroom during the investigation, ask students if they notice any patterns yet. Ask students what additional information they might need to see patterns in their data.

- Was there a pattern in what kinds of materials the magnet interacted with without touching?
- What additional data would help you determine what kinds of materials magnets interact with without touching?

3. Building Understandings

15 MIN

Materials: science notebook, *Magnet interactions lab*, *Composition of Metal Objects*

Hold a Building Understandings Discussion. When all groups have finished the investigation and have had a few minutes to write down their responses to the discussion questions, bring students together for a whole-group discussion. Use the questions on **slide D** to guide the discussion.

Key Ideas

Purpose of the discussion: To build a shared understanding about what magnets can push and pull on and to review ideas about attractive and repulsive forces from previous grades and the *Contact Forces* unit.

Listen for these ideas:

- Whenever there is a force (a push or a pull) on one of the magnets, there is also the same kind of force on the other magnet.
- When both magnets are pushing, the two are repelled (move away from each other), and when they are both pulling, the two are attracted (move toward each other).
- In a system with two magnets, we can get them to switch the type of force they are producing (attractive vs. repulsive) if we flip the orientation of one of the magnets.
- A compass is a magnet.
- Some metals are pushed and pulled by magnets (like iron), and some are not (like copper).

Additional Guidance

This is a good place to formally introduce the vocabulary of *attraction* and *repulsion* if you think these words will be new for your students.

Say, *We have been talking a lot about things being pulled together. How do the magnets move when the forces between them are both pulling?* Look for students to say that magnets will move toward each other. Then say, *When things move toward each other, we say that they are attracted to each other. So, forces that pull things together are often referred to as "attractive forces".*

Ask, *How do the magnets move when the forces between them are both pushing?* Look for students to say that magnets will move away from each other. Then say, *When things move away from each other, we say that they are repelled from each other. So, forces that are pushing things apart are often referred to as "repulsive forces" because they make things repel.*

The next few times you use *attraction* and *repulsion*, paraphrase them as forces that are pulling together vs. pushing apart the two objects in the system. Use gestures to indicate moving together and moving apart.*

Discuss the magnet-magnet interactions. Pose the first discussion question:

- Which materials (if any) produced both attraction (pulls) and repulsion (pushes) with the magnet?

*** Attending to Equity**

For students who are learning English, support the development of new vocabulary more explicitly. When developing new vocabulary, some strategies that may benefit emergent language learners are to use student-friendly definitions, make connections to cognate words when possible, and include a visual representation of the word.

Throughout this lesson, remind students: *We call forces that pull things together <u>attractive</u> and forces that push things apart <u>repulsive</u>.* Write these words at the front of the room next to a diagram indicating pulling together and pushing apart. Use hand gestures when you use these words to mime a push and pull and to help students make connections to these everyday terms. Consider adding these words to a word wall or having students add them to a personal glossary. For more information on *Developing Scientific Language*, refer to this section of the *Teacher Handbook*.

Look for students to agree that they noticed both attractive and repulsive forces with the other magnet (and maybe the compass). If students aren't sure, give them a minute to test out this idea in their groups.

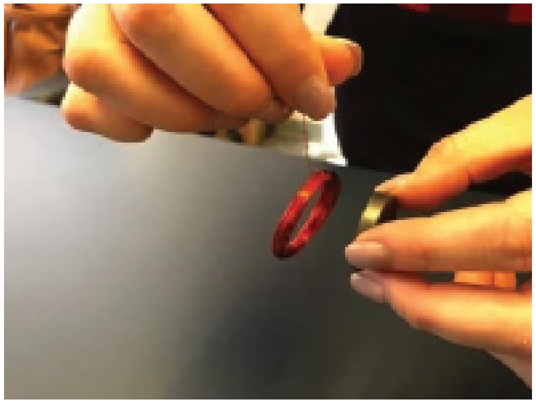
Begin by discussing the other magnet. Pose the next discussion question:

- For those materials that produced both attraction and repulsion, how did you get the forces to switch from pushes to pulls and back again?

If necessary, give groups a minute to play around with the magnets again. Establish consensus that if you flip one of the magnets, the forces will switch direction.

Say, *Interesting! So when we have two magnets, we can get them to produce forces that are attractive, or pulling toward one another, AND we can produce repulsive forces, or ones that push them away from each other, simply by flipping the orientation of one of the magnets.*

Display **slide E**. Ask, *When we bring a magnet close to another magnet, do you notice forces on only one of the magnets or is it happening on both of them?* Have students turn and talk for a minute. Then ask students to share their responses with the whole class. If necessary, give groups a minute to play around with the magnets again. Establish consensus that the magnets are pushing and pulling on each other.



Connect to contact forces. Ground the discussion in a review of the ideas from the *Broken Things* unit. Say, *It seems like whenever there is a force on one magnet, there is also the same kind of force (a push or a pull) on the other magnet at the same time. This makes sense because when we learned about contact forces, we figured out that forces always come in pairs. Turn and share an example of a pair of contact forces where two things are touching.* After a minute, elicit 2-3 examples of contact force pairs (e.g., the phone pushes down on the ground and the ground pushes up on the phone; the bat pushes the ball and the ball pushes the bat).

Make sense of the other materials that interact with a magnet. Say, *We decided that only the magnet (and compass) produced both pushes and pulls. But what else did the magnet interact with?* Spend no more than a minute or two eliciting general student observations about patterns they noticed. Ask, *Which test objects felt like they were being pulled toward the magnet?*

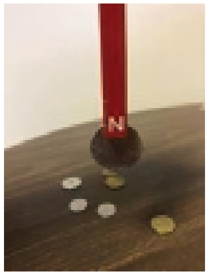
Look for students to list the the paper clip, the iron nail, the compass needle, the disc magnet. Say, *Did the copper coil interact with the magnet at all?* Students should say "no". Hold up a coil to a magnet to reinforce the lack of interaction. Say, *That's interesting. The magnet is not interacting with the wire, even though it is metal.*

Suggested prompts	Sample student responses
Why do you think you could feel forces between the magnet and some of the metal objects but not others?	*Maybe these are a different kind of metal. I've heard that maybe iron is attracted to magnets.*
What kind of additional data do we need to figure this out?	*It would be helpful to know what kind of metal these are all made out of.*

If students don't suggest the idea of needing to know about what metals the objects are made of, you can still say that you have some data about what metals are in these objects that might help us answer this question.

Pass out the student reference sheet *Composition of Metal Objects* (one per group is sufficient) that lists the metals in each object. Display **slide F**.

Additional Guidance



US coins do not interact noticeably with magnets, even though pure nickel is a magnetic metal. Five-cent coins do not have enough of the metal nickel in them to be effectively magnetic. But many coins from other countries are magnetic, and will produce magnetic forces when brought near a magnet. The coin in the photo is from Ecuador, and it is easily picked up by a bar magnet.

If you can get your hands on international coins, consider letting students experiment with which coins interact with the magnet, and presenting them with the metals that make up these coins using the format found in *Composition of Metal Objects*. For example, since 2012, the Canadian loonie (or one-dollar coin) is made of steel, which is an alloy of iron.

Do a think, pair, share. Give students time to process this table on their own and then ask them to share with a partner (or in groups). Finally, bring the class together to identify patterns in the data.

Suggested prompts	Sample student responses
What can this table tell us about the metals that interacted with the magnet to produce forces?	*The ones that had iron were attracted, but the other ones were not.*
How can this help explain why there wasn't any force between the coil of wire and the magnet?	*Because the coil of wire is made out of copper, which is not pulled by a magnet (and vice versa).*

Establish that the compass is also a magnet. Say, *So it sounds like some metals can produce attractive force pairs with the magnet and get pulled but not repulsed. Some of you mentioned that you got both kinds of forces with the compass in addition to the magnet*. Remind students to go back to their data sheet in their notebooks if they don't remember this. Say, *That's interesting that we were able to get the same forces on the compass as on the other magnet. What do you think that means about the compass needle?* Display **slide G**. Pose the question on the slide as a Turn and Talk:

- Is the compass needle a magnet, or is it just made of a metal that interacts with magnets, like iron? Why do you think that?

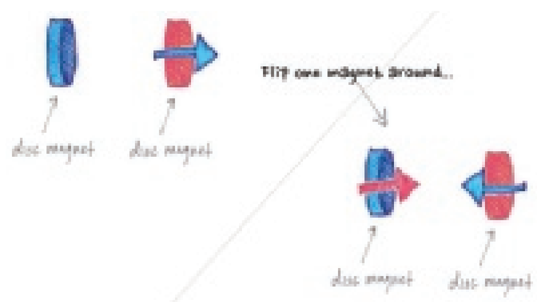
Elicit student responses. Look for students to suggest that the compass is probably also a magnet because it produces both pushes and pulls, whereas if it were made of only iron it would only produce pulls. Students may also argue that it flips around when you flip around the magnet that you bring near it, which other magnets do but not pieces of metal made of iron. If students are unsure about the compass needle, it is not necessary to establish consensus. What is important is that the students recognize that compasses respond to a magnet with directionality; in other words, the compass needle changes direction when its orientation (or the orientation of the magnet) moves. If students are not yet convinced of this, ask them to move a compass completely around the outside of a magnet slowly. They should notice the needle changing direction.

Record students' ideas in their Progress Trackers. Say, *We've developed a couple of really important ideas today. Let's start to keep track of some of these ideas in a Progress Tracker in our notebooks.* Display **slide H**.

Have students count out 10 pages in their science notebooks after the table of contents, if they have not already. At the top of the first page they should record the driving question for the unit and draw a T-chart below it. Then they should label the left side of the T-chart "Question/Lesson #" and the right side "What I figured out," as shown on the slide. Direct students to record the lesson question in the left column of the table (What can a magnet pull or push without touching?), along with the lesson number. Then have students add their ideas in the right column. Remind them that they can use any combination of words and pictures to record their ideas. An example of what students might record is shown below.

Additional Guidance

Remind students that the Progress Tracker is a thinking tool that is designed to help them keep track of their ideas. The sample Progress Tracker included in these materials serves as teacher guidance for what students may say at various points throughout the unit. Some students may say more, others may say less. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment. In this way, the Progress Tracker can be used to formatively assess individual student progress throughout the unit. When the class comes to consensus in future lessons, students will record this in their Progress Tracker with sources of evidence, making it clear that this is a classroom consensus model, not a record of individual thinking.

<table>
<tr><th>Question / Lesson #</th><th>What I figured out</th></tr>
<tr><td>"What can a magnet pull or push without touching?" (Lesson 2)</td><td>

Whenever there is a force (a push or a pull) on one of the magnets, there is also the same kind of force on the other magnet.
When both magnets are pushing, the two are repelled (move away from each other), and when they are both pulling, the two are attracted (move toward each other).
In a system with two magnets, we can get them to switch the type of force they are producing (attractive vs. repulsive) if we flip one of the magnets.
A compass needle is a magnet.
Some metals are pushed and pulled by magnets (like iron), and some are not (like copper).
</td></tr>
</table>

If there is time, ask 2-3 students to share some of the important ideas that they decided to record. Highlight student ideas that align with the key ideas developed in the Building Understandings Discussion.

Additional Guidance

Use strategic talk moves to highlight key ideas. When you hear an important idea, you can (1) revoice the idea, (2) ask others to restate the idea that the previous person shared, and (3) ask others to share what about their own ideas is similar to it. These talk moves allow students to spend more time with these ideas, providing space for other students to work with refining and solidifying these ideas.

4. Navigation: Exit Ticket

5 MIN

Materials: scraps of paper for exit ticket

Motivate further investigation of the coil. Remind students that the coil of wire and the magnet did not interact, but we are not ready to give up yet on the idea that there might be pushes and pulls between these two objects when they are part of the speaker system. Display **slide I**. Ask students to respond to the following question as an exit ticket: *Is there something we could do to cause the coil to interact with the magnet?*

Exit Ticket

Read student responses. Look for students to suggest that the copper coil needs to be connected to something, like the music player, electricity, current, or a battery. If most students are struggling to suggest something feasible, consider starting the next class by bringing in the homemade speaker for the students to examine the parts of the system. What is missing from the coil-magnet system that we think makes the speaker system work? Otherwise, begin the next class by telling students that a lot of people suggested in their exit tickets the need to provide a source of electricity in the system.

Say, *Let's investigate this more next time we are together.*

Additional Guidance

Consider giving students time to share the word for magnet in another language on the second day of this lesson. To support this, at the end of day 1, ask students to research the word for magnet in another language by speaking to their friends and family or by looking it up. Multilingual students may be ready to share right away. Creating this space will honor the knowledge brought by family and community in the classroom, legitimize the resources emergent multilinguals bring to the classroom, and give emergent multilingual students the opportunity to make content connections in their first language.

The word *magnet* probably comes from a region in Greece where magnetic material was found, known as *Magnesia*. The root of the word is found in many languages, including German and Danish (*magnet*), Dutch (*magneet*), Italian, and Portuguese (*magnete*). In Spanish (*imán*) and French (*aimant*), the words most commonly used for magnet comes not from Magnesia, but from an ancient Greek word meaning invincible (*adámas*). The character for magnet in Chinese has the character for stone. Students may come with other ideas, stories and interpretations for these words. This is a chance for them to share their knowledge without judgement.

End of day 1

5. Navigation: Making Predictions

5 MIN

Materials: science notebook

Motivate discussion about the battery. Say, *We noticed that the magnet and the coil of wire did not interact with each other at all when we took them out of the speaker. But we were not ready to give up on the idea that there might be pushes and pulls between these two objects when they are part of the speaker system. Last time we met, several people suggested that electricity might cause the coil to interact with the magnet. So today I brought in some batteries for us to try connecting to the copper coils.*

Display **slide J**. Have students turn to a partner, and discuss the question on the slide:

- What will be the effect on the coil and the magnet when we connect the coil of wire to a battery?

Say, *This question is about cause and effect. It asks, what will be the effect when we make a change to the system? So let's use our cause-effect sentence starters to make predictions about what will happen when we connect the coil of wire to a battery. We are predicting that when we connect the copper coil to a battery, then ... what is the effect we will observe?*

Display **slide K**. Ask students to label a new page in their science notebooks "What will be the effect on the coil and the magnet when we connect the coil of wire to a battery?" This will be the investigation question for the lab. Underneath, they should write "Prediction:" and record their cause-effect prediction using the structure introduced in Lesson 1: "When we _____, we will observe _____."

Additional Guidance

Some students may draw connections to the *Sound* unit, hypothesizing that waves of sound or vibration are moving through the wire. This is a thoughtful explanation that draws on their scientific understanding but does not accurately describe the phenomenon. If this explanation comes up, frame the discussion around the two competing explanations. Make a T-chart with the electricity explanation on one side and the vibration explanation on the other side. Frame the battery-coil experiment as a way to decide between the competing explanations. If the vibrations idea is popular in your classroom, you might also consider testing the alternative explanation by having students brainstorm something that makes a sound but definitely doesn't have a source of electricity, such as a drum or another instrument that has no batteries and isn't plugged into the wall. Try attaching the wires of the coil to the drum and seeing what happens. Does the speaker make a sound? Is the coil pushed and pulled by the magnet?

Supporting Students in Three-Dimensional Learning

The cause-effect scaffolds built into the unit are designed not only to highlight connections across disciplines but to support engagement in science and engineering practices and disciplinary core ideas. In Lesson 1, students used sentence frames to support the development of NGSS Science and Engineering Practice 1: Asking Questions and Defining Problems while developing questions for the DQB about cause-and-effect relationships in the system. When students are using the fill-in-the-blank scaffold to articulate observations, the structure should be as so: When we [cause], we observe [effect].

In this lesson, students use this scaffold to articulate testable predictions (part of NGSS Science and Engineering Practice 3: Planning and Carrying Out Investigations) about cause-and-effect relationships in the system. When students are making predictions, the structure of the fill-in-the-blank scaffold should be

6. Connect the coil of wire to a battery.

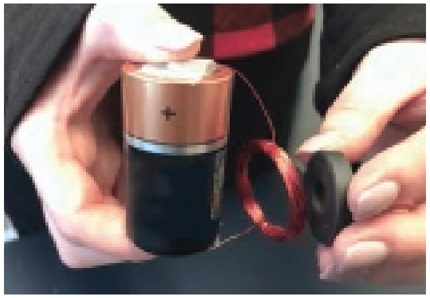
20 MIN

Materials: Magnet and coil interactions investigation, science notebook, chart paper, markers

Safety Precautions

CAUTION: Never plug the wire into an outlet. Only connect the wires to a D cell battery (provided). Be aware that if left connected to the battery, the coil will become hot to the touch and drain the battery. Tell students to disconnect the wire from the battery when they are not testing their system. Be sure that all wires are disconnected from the batteries when you put the supplies away at the end of class. Do not store the batteries in the same container as the coils of wire or the magnets. Store the batteries so that the opposite ends do not touch each other. One option is to use the tape from the investigation to cover the ends of the batteries before storing.

Organize students for the investigation. Divide the class into groups of 3-4 and instruct one team member in each group to get a battery, coil of wire, two pieces of tape, and a ceramic disc magnet for their team. Present **slide L**. Demonstrate for students how to use tape to attach the ends of the wire to the terminals of the battery. Have them look at the pictures on the slide and in the *Student Procedures* for reference.



Allow students to develop their own procedure for observing the movement of the coil. If students are struggling to see an effect, suggest that they let the coil hang from the battery and move the magnet close to it, making it swing back and forth. If groups still don't see an effect after trying this, suggest that the longer the length of wire that the coil is hanging from (the longer the pendulum length), the easier it will be to detect changes in its movement when bringing the disc magnet close to it.

Additional Guidance

As you move from group to group, ask students what they observe. Ask probing questions to clarify student thinking and highlight the ideas that students suggest about

- what they did to get the magnet to push the coil away versus what they did to get the magnet to pull the coil toward it and
- whether the coil is doing the same thing to the magnet that the magnet is doing to the coil (being attracted or repelled by it).

Establish a convention for representing forces. After five minutes, bring the class back together to discuss how to represent pushes and pulls in a diagram.

Say, *It sounds like we all agree that the magnet and the coil have forces between them when we connect the coil to a battery.*

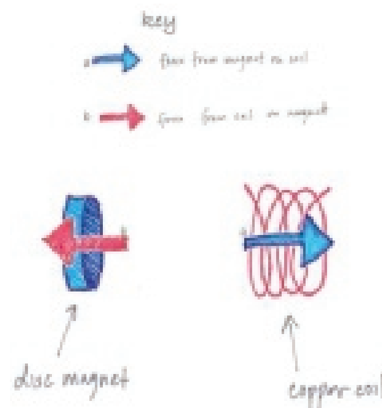
like this: When we [cause], we will observe [effect]. Note the addition of the word "will."

At the end of the lab students fill out a table structured around this language to organize and interpret their data (part of NGSS Science and Engineering Practice 4: Analyzing and Interpreting Data). They then return to what they wrote here, using the table to compare their observations to their predictions and to articulate something they figured out about forces (NGSS Disciplinary Core Idea MS-PS2).

Suggested prompts	Sample student responses	Follow-up question
Were the forces strong enough for you to feel them pushing back on you when you held the coil and the magnet close to each other?	*no*	
What did you do to detect the forces?	*We hung the wire off the battery and moved a magnet close to it and watched for it to swing.*	*What were you looking for to indicate that there were forces?*
So it sounds like instead of feeling the pushes and pulls, you were looking for the coil to move. Does a force always make something move?	*no* *Yes, but sometimes it is at a microscopic scale.*	

Display **slide M**. Say, *You may remember from earlier units that when something moves, we say it has motion energy or kinetic energy.* Pose the question on the slide as a Turn and Talk, *Do magnetic forces transfer energy? What evidence would we look for to determine if energy had been transferred to or from an object in the system? Turn to a partner and share your ideas.*

After a minute, elicit 2-3 student ideas. Look for students to suggest that if we see movement, energy is probably transferred.



Revisit the convention developed in earlier units for representing forces. Say, *How do we represent the forces on these objects when the magnet and the coil are repelling each other or pushing each other away?*

Encourage students to review the convention that we used in previous units to indicate forces. Show **slide N**. Create a key at the front of the classroom (e.g., on chart paper) to keep track of these conventions. We recommend using both color and labeling conventions, matching the colors and labels used for the magnet to the force on the coil and used on the coil to the force on the magnet. Leave room on the key to add more conventions in upcoming lessons. Make sure the key stays visible over the course of the unit.

Do the investigation. Pass out *Magnet and coil interactions investigation* and ask students to follow the investigation procedures. Ask students to mark their initial setup by putting stickers on the coil and the magnet to indicate the sides that are facing each other when the force is a push. Then have students follow the directions to fill in the table with their results. After recording each observation, they should return the coil and the magnet to the initial setup.

Additional Guidance

At this point the stickers don't need to correspond to north or south poles, nor does this vocabulary need to be in use. If both stickers are on the north, that is fine, or if both stickers are on the south, that is also fine. Students will develop the vocabulary of *north and south poles* later in the unit (Lesson 4).

As students are finishing up their observations, display the discussion questions on **slide O**, also available on *Magnet and coil interactions investigation*. When they are done with their observations, they should discuss these questions in their groups.

7. Building Understandings

10 MIN

Materials: science notebook, magnet

Hold a Building Understandings Discussion. Elicit student responses to the questions on **slide O**:

1. Turn back to the prediction you made in your notebook. How did your results compare to your prediction?
2. Is there a force on the magnet from the coil? How do you know?
3. Is there a force on the coil from the magnet? How do you know?
4. What can we do to switch the direction of the force between the magnet and the coil?
5. Did the kinetic energy of the magnet or coil of wire change? How do you know?

Key Ideas

Purpose of the discussion: To build a shared understanding about attractive and repulsive forces between the magnet and the coil of wire.

Listen for these ideas:

- There are forces between the magnet and the coil when the coil is connected to the battery.
- Just like in a system with two magnets, we can get both pushes and pulls (repulsive and attractive forces) between the magnet and the connected coil.
- Just like in a system with two magnets, we can get the connected coil of wire and the magnet to switch the type of force they are producing (attractive vs. repulsive) if we flip the orientation of either one of them.
- When the connected coil of wire or the magnet move, they have kinetic energy.

Assessment Opportunity

Listen to determine whether students are thinking about both pushes and pulls (repulsive and attractive forces) between the magnet and the coil of wire. Probe student thinking to make sure that students are associating repulsive forces with pushes, where the arrows point outward in the diagram, and attractive forces with pulls, where the arrows point inward in the diagram. If students do not make these associations, it is an indication that they are struggling to develop a conceptual model for directionality of forces. Consider using the following kinesthetic activity to reinforce this idea: Have students stand in pairs facing each other. Each pair should choose which student will be the coil connected to the battery and which student will be the magnet. Ask students to hold their arms out parallel to the floor and imagine what would happen if they pulled on each other (if you feel comfortable asking your students to gently pull on each other, do so). Did they move toward each other or away? Is that attraction or repulsion? Do the same exercise for students pushing on each other. Finish by discussing with students 1) how this model works well as an analogy to the wire and magnet system (pushes and pulls bringing things apart and together) and 2) how the model falls short (contact forces versus forces at a distance).

Say, *We've developed a couple of really important ideas today. Let's keep track of these ideas in the Progress Tracker in our notebooks*. Display **slide P**. Students will have already recorded the lesson question on the left side of the table. They should record their new ideas on the right side of the table, under their ideas from yesterday. Remind them that they can use any combination of words and pictures to record their ideas. If there is time, ask 2-3 students to share some of the important ideas that they decided to record. Highlight student ideas that align with the key ideas developed in the Building Understandings Discussion:

- There are forces between the magnet and the coil <u>only when</u> the coil is connected to the battery.
- Just like in a two-magnet system, we get both pushes and pulls (repulsive and attractive forces) between the magnet and the coil.
- Just like in a two-magnet system, we can get the coil of wire and the magnet to switch the type of force they are producing (attractive vs. repulsive) if we flip the orientation of either one of them.
- When the coil of wire or the magnet move, they have kinetic energy.

8. Navigation

10 MIN

Materials: None

Elicit ideas about energy transfer. Display **slide Q**. Say, *The speaker is a system.** One of the ways to understand a system is through energy flow. Let's think about the energy in this system for a moment. We know that moving objects have kinetic energy. In the* Broken Things *unit and the* Sound *unit, we figured out that contact forces transfer energy during collisions. But where do you think that energy came from if the parts of the speaker are not touching? How did it flow through this system? Turn to a partner and share your ideas.* Accept all ideas but look for students to suggest energy transfer through air.

- If students suggest energy transfer through air, say, *Some people think energy may be transferring through the air. That was part of our explanation for what happens when sound travels through the air. Maybe this system is similar to that. Let's investigate it next time.*
- If students do not suggest energy transfer through air, say, *We have a lot of ideas about where the energy comes from. Let's investigate more next time.*

In this lesson, we are expecting that some students suggest energy transfer through air in the speaker system. Regardless of whether the idea is wrong or right, this is a well-informed idea based on our ideas about energy transfer from the *Sound* unit. Students who put forward this theory are transferring content knowledge and exercising scientific reasoning.*

Elicit student ideas about the coil of wire as an exit ticket. Display **slide R**, which prompts: Is the coil of wire a magnet? Why or why not? Use at least one cause-effect relationship to justify your response.

*** Supporting Students in Developing and Using Systems and System Models**

This is another opportunity to remind students that the speaker represents a system, which is a group of related parts that interact in ways that allow the entire whole to carry out a function that individual parts cannot. Here, students begin to think about energy flows in the speaker system. They will come back to this in Lesson 3, and flesh out their initial ideas in Lessons 7 and 8.

Exit Ticket

The purpose of this exit ticket is to give students a chance to

1. reinforce the idea that the coil of wire becomes a magnet when it is connected to a battery,
2. set students up to earn the word *electromagnet* at the beginning of Lesson 3,
3. justify a claim with evidence, which is fundamental to the practice of explanation, and
4. practice using cause-effect relationships specifically as evidence to justify a claim, which is the precursor to the kind of hypothesis-building that they will do in Lesson 3.

Assessment Opportunity

Use this exit ticket to determine if students are understanding (1) that the coil of wire exhibits the properties of a magnet only when attached to a battery and (2) how to use cause-effect relationships to justify a claim. Do not worry about whether students respond "yes" or "no" but rather how they justify their claim. Look for responses that integrate both of these understandings, such as the following:

- Yes, because when we connect the coil of wire to the battery, then we observe that it acts like a magnet.
- Yes, because when we connect the coil of wire to the battery, then we observe that it pulls and pushes on the magnet (or gets pushed and pulled by the magnet).
- No, because when we put a magnet near the coil of wire (without the battery), then we observe that there are no forces.
- Sometimes/maybe, because when we put a magnet near the coil of wire (without the battery), then we observe no forces, but when we connect the coil of wire to the battery, then we observe forces.

Students who need more support might have answers that make a claim but either do not justify that claim or do not use both clauses from the cause-effect framework to justify the claim, such as these examples:

- Yes/No/Maybe. (claim only)
- No, because it doesn't act like a magnet. (claim + effect only)
- Yes, because there are forces on it. (claim + effect only)
- Not unless we connect it to the battery. (claim + cause only)

If necessary, spend some time at the beginning of the next lesson reinforcing the cause-effect structure before moving on to hypothesis building. Remind students that we can use the "when we ________ we observe ________" sentence structure to talk about our *observations* when we change something, or we can add the word *will* ("we will observe …") to make predictions about what we think will happen when we change something.

*** Attending to Equity**

It is valuable to think of ideas like this not as misconceptions that need to be erased but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board. For example, many students believe that the seasons are caused by Earth being in closer proximity to the Sun during summer. This is a theory constructed from external evidence such as textbook images and supported by personal evidence like "When I get closer to a fire, it feels hotter." Simply telling students that this is wrong and explaining that the seasons are a result of the tilt of Earth is not as productive as investigating the inaccurate proximity theory and building evidence against it that will help students construct a new, more accurate conceptual model for Earth and the Sun. In the next lesson, we will spend time exploring the theory that energy is transferred between magnets through the air in order to build evidence for a more scientific conceptual model that includes invisible magnetic fields.

SCIENCE LITERACY: READING COLLECTION 1

Day-to-Day Magnets

1. **Anatomy of Speakers**
2. **To Be, or Not to Be . . . Magnetic**
3. **Buzzers and Bells**
4. **Debate: Outlaw Magnets**
5. **Flip of a Switch, Turn of a Dial**

Literacy Objectives

- ✓ Use reading to describe what magnets and energy are and how they are used.
- ✓ Use information from reading to explain how electromagnets work.
- ✓ Support a position on restricting use of certain types of magnets.
- ✓ Differentiate magnetic from nonmagnetic materials.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 1–2.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an explanation of how magnets are used in earbuds in response to the reading.

Instructional Resources

Student Reader Collection 1	**Science Literacy Student Reader, Collection 1** "Day-to-Day Magnets"
Exercise Page EP 1	**Science Literacy Exercise Page** EP 1

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 1: What causes a speaker to vibrate?
- Lesson 2: What can a magnet pull or push without touching?

Standards and Dimensions

NGSS Performance Expectation MS-PS2-3: (Building toward) Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

Disciplinary Core Ideas PS2.B: Types of Interactions; **PS3.A:** Definitions of Energy

Science and Engineering Practices: Asking Questions; Constructing an Explanation

Crosscutting Concepts: Cause and Effect; Systems and System Models

CCSS

English Language Arts

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

hypothetical **obstruction**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

Exercise Page

EP 1

2. Preview the assignment and set expectations.

MONDAY

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Forces at a Distance unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *In "Anatomy of Speakers," you will find out how the parts of a speaker use magnetic force to produce and amplify sound.*
  - *"To Be or Not to Be . . . Magnetic" will tell you about the characteristics of magnetism.*
  - *In the third selection, you'll read about how magnets are used in producing sounds for warnings and alerts.*
  - *In "Debate: Outlaw Magnets," you'll find out how magnets can be dangerous!*
  - *The final selection will tell you about how electricity is used to start and stop magnetic energy.*

- Distribute Exercise Page 1. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to generate an explanation for younger children about how earbuds work.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

WEDNESDAY

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What is magnetism?	*It is a noncontact force.* *It is a force that causes a push or a pull.* *It's the noncontact force that certain metals have toward or away from other metals.*
How did people hear speeches, concerts, and loud warnings before there were speakers?	*They had to be close enough to hear. People who were speaking had to yell or use bullhorns. Buildings were constructed to have good acoustics, where sound would carry.*
Why are earbuds so useful?	*Earbuds fit in your ears, and only the listener can hear the audio being played through them. You can hear music or have a conversation without bothering anyone else. People with hearing problems can hear things they otherwise might not be able to hear.*
When might a magnet be dangerous?	*If magnets are attracted to each other, they can squash objects that stand between them, including body parts.*
What makes electromagnets so useful?	*You can turn them on and off.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
Why is magnetic force a force at a distance?	*Magnets push and pull each other or magnetic materials without touching.* *Magnetic materials can attract or repel each other without coming into contact.*
What would you need to build a homemade speaker?	*a magnet, a coil of wire, and a speaker cone*
Why do electromagnets use copper wire coils?	*Copper is not magnetic, but when strong magnets come near copper, the electrons on the surface of copper rotate. This helps create a magnetic reaction.*
Why is the copper wire coiled?	*The current passes through the wire. The more turns of the wire, the stronger the magnetic field is. A straight wire has just one turn.*

SUPPORT—Have students watch a video showing how magnets and copper interreact to help them understand why copper coils are used in electromagnets.

EXTEND—Have students make an electromagnet with copper wire, a battery, and an iron nail and demonstrate to the class how it works.

- Refer students to the Exercise Page 1. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to create an explanation of how earbuds work so that a third grader can understand.*
  - *In the selections, you read about how magnets are involved in creating sound waves that come from speakers.*
  - *Think about what you read and experienced as you explored creating a homemade speaker. What would be the best way to explain that to a third grader?*
  - *Write or draw and label your explanation.*
  - *Make your explanation engaging so that a third grader will be able to understand what you are explaining. A great explanation will be simple and understandable.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 1

4. Facilitate discussion.

FRIDAY

Facilitate class discussion about the reading collection and writing exercise.

The five reading selections help to explain how things that students use every day use magnets to create energy.

Student Reader

Collection 1

Page 4 Suggested prompt	Sample student response
What is the general purpose of the first selection, "Anatomy of Speakers"?	*It shows and explains how copper coils, magnets, and speaker cones are arranged and interact to make sound.*

Page 4 Suggested prompt	Sample student response
What do sound waves have to do with speakers?	*The speaker cone translates the movement created by the magnet and copper wire vibrations into sound waves that travel through the air. Speakers push molecules as sound waves through the air to your ear.*
What does a diaphragm do in an ear-bud?	*The diaphragm is the thin material attached to the voice coil. The vibration of the diaphragm produces sound waves. This is what the cone does in a speaker.*

Page 5 Suggested prompts	Sample student responses
What is the general purpose of the second article, "To Be, or Not to Be . . . Magnetic"?	*It explains what types of materials are and are not magnetic.* *It describes the characteristics of magnets.*
How can you test to see if something is magnetic?	*Touch it with a magnet to see if you can feel a push or pull.* *Hold a magnet near a material and see whether it moves toward or away from the magnet.*
What are some metals that do not react to magnets?	*aluminum, brass, silver*
What are some ways magnets can be used to attract or repel other metals?	*A magnetic screwdriver can keep iron screws in place while setting them.* *A metal detector can find lost metal objects on a beach.*

Pages 6–7 Suggested prompts	Sample student responses
How does the third selection help you build knowledge on top of what you learned in the first selection?	*The first selection was about magnets used in speakers. This selection shows how the same elements are used in alarms, bells, and warnings.* *Devices that produce noise use similar parts, like magnets, to work.*
How do magnets make sounds in a doorbell, fire alarm, or siren?	*the same way they are used in a speaker with a magnet, a copper coil, and a speaker cone*
What are some other uses of sounds made by magnets and copper coils?	*radio, smoke alarm, seat belt warning, telephone, low battery warning*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Some students may benefit from differentiating between a magnet and an electromagnet. Discuss how an electromagnet is a temporary magnet that can be turned off and on with electric current and can be made stronger or weaker. A magnet keeps its magnetism and the same strength.

CHALLENGE—Have interested students research the history of electromagnets so they can tell the class about different applications of electromagnets that we have today.

EXTEND—Have students watch a video that shows how headphones or earbuds work.

Pages 8–9 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth article, "Debate: Outlaw Magnets"?	*It describes a debate about banning small magnets because children swallowed them and damaged their insides.*
How could a buckyball hurt a child?	*If the child swallowed a few of them, they could attract each other inside the body and block or hurt inner organs.*
Do you think the buckyball ban was a good idea or not?	*It was good because they could cause harm and required warnings to make it clear that the toy was potentially dangerous to small children.*

Pages 10–11 **Suggested prompts**	**Sample student responses**
How does the last selection relate to the other selections in this collection?	*It focuses specifically on electromagnets and how useful they are in so many modern appliances and machines.*
Why do some people warn about using magnets near computers?	*Computers use magnets to power and store data. In early computers, people were concerned that magnets near a computer could damage the data on the disks and monitors that used magnets. But today's computers do not have these problems.*
Would riding on a maglev train be smooth or bumpy?	*It would be smooth, because they are riding on a cushion of air. A maglev train uses electromagnetism to move, so it hovers over tracks (for a smooth ride) rather than moving on the tracks (which would be a bumpier ride).*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 1, students should create an explanation of how earbuds work so that third grade children could understand it. It could be in any form, such as a poster, a drawing, or an explanatory graphic.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 3

How does energy transfer between things that are not touching?

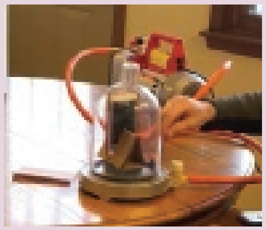
Previous Lesson

We experimented with several objects to establish that while certain metals do interact with magnets, including other magnets, the copper coil did not until we connected it to a battery. We could change the direction of these forces by changing the orientation of either the magnet or the coil of wire.

This Lesson

Investigation

1 DAY



We are wondering how energy could transfer between parts of the speaker when the parts aren't touching. We think the energy might be transferring through the air. We write two hypotheses that predict the cause-and-effect relationships we would observe if energy transferred between magnets through the air. We use evidence from two whole-class investigations to show that these hypotheses are false. We aren't sure what's going on in the space between two magnets, and we need to investigate more.

Next Lesson

We know that the "bubble" we feel around a magnet is not air, but we still don't know what "it" is. We will learn that this space is called a magnetic field and that we can test this space with objects like tiny pieces of iron metal and compasses to learn more about magnetic fields. We will also look for magnetic fields in our everyday lives using compasses and document them.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Develop and test a set of hypotheses to produce evidence that energy can transfer between magnets without transferring through matter, causing the magnets to move.

Construct an argument supported by empirical evidence and scientific reasoning that energy can transfer between magnets without going through matter, causing the magnets to move.

What Students Will Figure Out

- The energy that makes magnets move when they get close to each other does not transfer through air.

Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	15 min	**NAVIGATION: MAKING PREDICTIONS** Review where we left off in the previous lesson and hold a discussion to elicit student ideas about what could be going on in the space in between two magnets or between a coil with a current and a magnet.	A-E	*Framing Hypotheses*, chart paper, markers
2	10 min	**DEVELOP HYPOTHESES IN SCIENTISTS CIRCLE** Students work as a class to develop testable hypotheses to determine the role air plays in the transfer of energy through magnetic forces between two magnets.	F	chart paper, markers
3	10 min	**TWO WHOLE-CLASS INVESTIGATIONS** We do two whole-class investigations together to gather evidence to determine if our hypotheses about the need for air in energy transfer from magnetic forces holds true.	G-L	Investigating Air
4	5 min	**MAKING SENSE AND HOME LEARNING** Use the evidence we collected to support or disprove the consensus hypothesis. Ask students to build an explanation as home learning.	M	
5	5 min	**NAVIGATION** The class will agree that they still don't know how energy is transferred through magnetic forces but they do know that air is not involved. Students will leave wondering about what is happening in the space between two magnets or between a magnet and an electromagnet.	M	
				End of day 1

Lesson 3 • Materials List

	per student	per group	per class
Investigating Air materials	• science notebook • *Blocking Air Investigation*		• 2 magnets • 1 3″ × 5″ index card • 1 3″ x 5″ piece of cardboard • Sound Source in a Vacuum Chamber - Unit 8.3 Forces at a Distance Lesson 3 video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • chart paper • markers
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Framing Hypotheses*		• chart paper • markers

Online Resources

Materials preparation (5 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Note: Though items can be prepared beforehand, consider not initially including any specific materials for the investigations. Instead, give students more open-ended options in thinking through investigation plans.

First Whole-class Investigation: Blocking Air

- **Group size:** Class
- **Setup:** You will need access to two small ring or bar magnets, a coil of wire, a 9-volt battery, a 3x5 note card, a 3x5 piece of cardboard, and a ruler. Watch the Magnets and Matter video to see the setup. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Second Whole-class Investigation Part 2: Removing Air

- **Group size:** Class
- **Setup:** Preview the Bell and Vacuum Chamber video that shows a magnet interacting with another magnet in a vacuum chamber but no sound being produced by a ringing bell. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

Students will develop the idea that energy is somehow transferred between two objects (i.e., two magnets or a magnet and an electromagnet) that are not touching and are attracted to or repulsed from each other even when there is no matter between them. In other words, matter is not required for energy to transfer between two magnets or between a magnet and an electromagnet.

Students will use empirical evidence to argue that magnetic forces and the energy transferred by those forces are fundamentally different from forces that cause sound and energy transfer through direct contact; a compressional wave of air particle collisions, and air itself, is not part of the mechanism that causes magnetic forces. In subsequent lessons, students will formalize the idea that magnetic forces are caused by nonmaterial fields produced by magnets and will discover how these fields can be studied and described using test objects.

Where We Are NOT Going

Some students may use the vocabulary of "magnetic fields" prior to this lesson or at the beginning of this lesson. Encourage these students to elaborate on what exactly they mean by "field." Some students may see a compressional wave model of magnetic interactions and a field model as being compatible. Even if some students have accurate descriptions of "fields" prior to or during the lesson, they can still experience this lesson as a means of gathering evidentiary support for their predictions about the role of air in energy transfer through magnetic forces. Students will not describe or map a field in this lesson.

1. Navigation: Making Predictions

15 MIN

Materials: science notebook, *Framing Hypotheses*, chart paper, markers

Establish that the coil is also a magnet (electromagnet). Remind students that we know there are force pairs between two magnets (including between a coil connected to a battery and another magnet). Remind students about the question from the exit ticket: *Is the coil of wire a magnet?*

Say, *Most people agreed that the coil of wire was not a magnet when it was by itself. But we were not as clear on what happens when we connect it to a battery. A lot of people pointed out that we were able to get the same interactions with the coil when it was connected to a battery as we got with the other magnet. What do you think that means?* Display **slide A**. Pose the question on the slide (a new version of the exit ticket from Lesson 2) as a Turn and Talk:

- Is the coil of wire a magnet when it is connected to a battery? Why or why not?

After a minute, elicit student responses. Push students to justify their responses. Look for students to point out that the coil of wire can produce both attractive and repulsive forces with the magnet, just like another magnet.

Then say, *Since all the evidence we've collected so far suggests that the coil of wire acts like a magnet when it is connected to a battery, I think we can just start calling it a magnet. Scientists consider it a special type of magnet, called an electromagnet.*

Say, But the electromagnet is a magnet only some of the time. This magnet [hold up a permanent magnet] *is always a magnet, so we call it a permanent magnet because it is permanently a magnet.* Record the words "electromagnet" and "permanent magnet" at the front of the classroom next to a sketch of the coil connected to a battery and of a permanent magnet and/or record these words in a personal glossary or class word wall.*

Summarize what we know and generate initial ideas. Remind students that we know that because forces are causing movement in our speaker system, energy must be transferred into the parts that are moving. Display **slide B**. Say, *When I kick a soccer ball, the energy transfers from my foot to the ball when they make contact. But inside the speaker, the magnet and the electromagnet are not touching! What is going on? How does energy move through the system if the parts aren't touching?* Ask students to respond to this question as a Turn and Talk.

Display **slide C**. Prompt students to sketch out initial ideas for how energy is transferred between two magnets. Say, *In your notebook, write our question: "How does energy transfer between things that are not touching?" Under the question write "My initial ideas" and individually describe what you think is happening in the space between the magnets.*

While the students work on their initial ideas, circulate around the room and look for a variety of different ideas, such as the following:

- The magnets send out special invisible matter that can push or pull on other magnets.
- A "field" exists around each magnet, and this field causes the forces.
- It works like sound: The magnets push a piece of air, which then collides with another piece of air and so on. Eventually, this compressional wave reaches the other magnet, pushing or pulling it.

*** Attending to Equity**

It can be very helpful for all students, and particularly emergent multilinguals, to break down compound words like *electromagnet*. Ask students to reason about the first part of the word by asking, *What does "electro" sound like? What other words have you heard that sound like that?* Students will probably say "electricity." Encourage students to consider and suggest cognate words in other languages as well, such as *electricidad* (Spanish), *électricité* (French), *elektrichestvo* (Russian transliteration), or *Elektrizität* (German). Then summarize the idea of putting both words together, "electricity" and "magnet", to make a single compound word that indicates that this is a different kind of magnet than a permanent magnet in that it needs electricity in order to become a magnet (cause and effect).

*** Supporting Students in Engaging in Asking Questions and Defining Problems**

Asking questions is a focal practice in this unit. In middle school, the NGSS specifies that as part of the development of this practice, students are expected to "frame a hypothesis based on observations and scientific principles," but only "when appropriate" (*Appendix F*, p. 5). These words are chosen carefully because asking questions, making predictions, and framing

Make predictions using the cause-and-effect table. Say, *I heard an interesting idea as I moved through the classroom that energy might travel between two magnets through the air. This does make sense based on our model for how sound travels, but what would it take to convince us whether the same mechanisms are at work here? How can we test whether this explanation is true? Turn and talk with a partner.*

Additional Guidance

If students are not convinced that we should make predictions about the potential role air plays in causing magnetic forces, ask students to voice why it would be important to rule out air as a factor in light of what we previously figured out about how sounds travel through the air and how energy is transferred through a compression wave.

After 2-3 minutes of partner talk, bring students back together and elicit ideas. Look for students to suggest changes to the system, such as these examples:

- We can put something in between two magnets (paper, wall, cardboard).
- We can put the magnets in a vacuum.
- We can put our hands in the air between the magnets.

Record student ideas about changes to the system on a piece of chart paper, leaving room at the top to add a title and space on the right to add text about the effect of each change. If a student gives a reason for making the change or a predicted effect, leave that out of what you record at this point. Then say, *Most of what I have recorded here are changes we can make to the system. This reminds me of the cause-and-effect relationships we have developed in previous investigations.* Display **slide D**.

Then ask, *Can we go back through each of these changes to the system that we recorded on chart paper and consider what effect we predict we would observe if we make these changes if this explanation about energy moving through the air is true? Share your ideas with a partner.*

As students discuss, pass out *Framing Hypotheses*.* Then elicit student ideas about effects that we might predict would be associated with the changes the class brainstormed on chart paper. Add these ideas to the poster in a new column and add the title: "If Energy Transfers through Air."

Develop cause-effect predictions in partners. Say, *Work with a partner to come up with two cause-effect relationships that you predict will tell us if this explanation is true.*

Assessment Opportunity

Students may not yet be using the word *hypothesis*, but this is what they are building in *Framing Hypotheses*. Look for students who are mixing up what goes in each of the columns, such as these examples:

- If the energy moves through the air, then we will observe the air moving.
- If I see the air moving, then we will observe the flag wave.
- If I see the flag waving, then we will observe that the energy moves through the air...

hypotheses are not the same thing. It is important to note the distinction between the types of predictions and questions students have been making up until now and the hypotheses they will write in this lesson. According to *Appendix H* of the NGSS, a hypothesis is an "idea that may contribute important new knowledge for the evaluation of a scientific theory" (p. 5). It is not simply the articulation of a pattern ("if this, then that"), but rather the articulation of a pattern that, if established, would lend support to a mechanistic model or explanation for a phenomenon.

In this lesson (Lesson 3), students begin by identifying changes they can make to the system and then turning these into predicted cause-effect relationships using the sentence starters. Students then pause to consider what makes these statements hypotheses rather than simply predictions—that establishing those cause-effect patterns through investigation will either support or disprove a model or explanation for the phenomenon. See *Using Cause-Effect Scaffolds to Support Science and Engineering Practices* for more detail on how these sentence frames are used across the unit to support student sense-making and engagement in the science and engineering practices.

These are logical ways to state a hypothesis, but they do not fit the structure of the scaffold as the class has been using it. In addition, use if/then statements to describe the cause-effect relationship, rather than the mechanistic explanation indicated by the cause-effect statement could set students up for difficulty understanding the distinction between a hypothesis and a prediction (see the Lesson 1 teacher reference, *Using Cause-Effect Scaffolds to Support Science and Engineering Practices*). Use probing questions to clarify the purpose of the scaffold. Ask these students, *Is this a change you can actually make to the system? If not, does it belong in this column? Is this an effect that we can actually observe or an effect that is maybe invisible?*

Display **slide E**. Have students turn to a new page in their notebooks and write the question on the slide: *What cause-effect relationship(s) do we predict we will observe if this explanation is true?* Under the question, they should paste *Framing Hypotheses*. Give students another five minutes to work with a partner to come up with two cause-effect statements before moving everyone into a Scientists Circle.*

2. Develop hypotheses in Scientists Circle. 10 MIN

Materials: science notebook, chart paper, markers

Introduce the hypothesis. Display **slide F**. Say, *What you have put together here is more than just a prediction. A* prediction *is an educated guess about what you think is going to happen. If your predictions are correct, that means that we have evidence to support this explanation about energy traveling through air. And if your predictions are wrong, that means that we have evidence against this explanation. When your cause-effect prediction can be used to evaluate an explanation or a theory like this, scientists call it a* hypothesis.

Additional Guidance

The Nature of Science in the NGSS

According to NGSS *Appendix H*, in middle school, students should learn that "theories are explanations for observable phenomena" and that "the term 'theory' as used in science is very different from the common use outside of science" (p. 5). Consider taking a moment to engage students in a conversation about where they have heard the word *theory* before. Students may suggest that a theory is an idea that hasn't been proven or an educated guess. Accept all responses and then tell students, *Scientists are very specific when they talk about a theory. A theory tells us how and why something happens that we can observe. We collect observable evidence of cause-and-effect relationships in order to lend support for a theory. The idea that air could be transferring energy between the magnets is an explanation, not a theory. It tells us a possible how and why for the vibrations in a speaker. But it does not explain a lot of different phenomena, so it is not a theory.*

You might consider sharing even more with students about the word *theory*. Sometimes, scientific ideas are said to be "just a theory." This is said about biological evolution, for example, or the link between anthropogenic greenhouse gases and climate change. This use of theory is often deployed in order to make it seem like these ideas are not widely accepted. In everyday talk, the word theory means just a hunch, but in science, a theory is a powerful explanation for a broad set of observed phenomena. A theory must be supported by many different kinds of evidence in order to be accepted by the scientific community, like evolution and anthropogenic climate change have. Even scientists sometimes use the word *theory* when they really mean an explanation, a hypothesis, or a hunch.

*** Attending to Equity**

Prior to convening in the Scientists Circle, circulate while students are working with a partner to preview their hypotheses and look for ideas about blocking air and removing air. Recruit a student who participates less frequently in whole-group conversations to share an idea they heard in their small-group conversation. You can quietly let the student you want to call on know about your intent in advance so they can think through their response ahead of time or let you know that they don't feel comfortable sharing. For example, you might say, *When we move to the Scientists Circle, I'd like to ask you to share this idea about blocking the air with the class. Would you be willing to go public with this really productive idea?*

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**

Students develop hypotheses in this lesson as a way to make predictions about the cause-and-effect relationships among magnetic forces, motion, and energy transfer. They also gain experience with how scientists work to gather evidence for their hypotheses, often figuring out how something *doesn't* work and eliminating their hypotheses. Point this out to students to prevent frustration. Students may be used

In high school, students will learn that a scientific theory can be disproven when the body of evidence weighs against it. According to NGSS Appendix H, "A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence."

Develop consensus hypotheses in Scientists Circle. Ask, *Does anyone want to share one of their hypotheses to get us started?* If no students volunteer, point out the different, thought-provoking hypotheses you noticed from the independent work and small-group conversations. Ask those students if they would go public with these ideas for the class so we can work with them together as a whole group. Highlight students' ideas about changing the system by blocking air or removing air from the system.

These are suggested consensus hypotheses:*

- If we put an object between the magnet and the electromagnet, then the object would move and/or there wouldn't be any forces between the magnet and the coil because moving air transfers energy between the magnet and the electromagnet.
- If we put the magnet and the electromagnet in a place with no air, then there wouldn't be any forces between the magnet and the electromagnet because moving air transfers energy between the coil and the magnet.

Record the consensus hypotheses at the front of the room on chart paper and ask students to also record them in the second table of *Framing Hypotheses*.

to collecting evidence to prove something correct but unfamiliar with collecting evidence to prove something is not correct. As students plan investigations, push them to describe how evidence collected will help them understand what is happening in the space between two magnets.

3. Two Whole-Class Investigations

10 MIN

Materials: Investigating Air

Plan investigations to test our hypotheses.* Stay in the Scientists Circle. Display **slide G**. Say, *These are really great hypotheses. Let's think of some ways we might gather evidence to help us figure out if they are true. With a partner, brainstorm ways we could test these cause-effect relationships to establish whether air is involved in causing energy transfer through magnetic forces.*

After 2-3 minutes, ask students to share ideas. Record ideas on the board or chart paper. Some expected ideas are as follows:

- We could try to remove air with a vacuum and see if the magnets still "work."
- We could try to block the air with something and see if the magnets still move.
- We could do some research using a reputable source.

For the first whole-class investigation, focus on ideas for blocking air.

Suggested prompt	Sample student response
What could we use to prevent the air around one magnet from reaching another?	*Place something solid between the magnets, like paper, cardboard, a container (box or tub), or a brick or rock.*

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**
Do not spend too much time on this review of independent and dependent variables. If the class does not remember this distinction, you will have a chance to review these variables in this lesson, and again in Lesson 7, and Lesson 10. Over the course of this unit, you will build on the ideas from Unit 8.1 Broken Things, using the cause-effect sentence frames scaffold to make strong connections between asking questions, formulating hypotheses, and choosing variables to test.

Suggested prompts	Sample student responses
If air does play a role in energy transfer through magnetic forces acting at a distance, what would we expect to observe if the two magnets are close but a note card is blocking the air between them?	*No force will occur if collisions between air particles are necessary for the interaction of magnetic forces and something is blocking the air particles in the path between the magnets.* *We may see the note card between the magnets move as air particles around the magnets collide with the card.* *The experiment is flawed. It is possible that compression waves can travel through a note card, and this is something we couldn't easily observe.*
How can we make sure that this is a fair test? How will we know that it is the note card that is stopping the magnets from transferring energy and not some other variable?	*We should have a control group where we place the magnets at the same distance away from one another and in the same orientation but without a note card or other object placed in between them. Then we can compare how the magnets move.*

Determine variables. Display **slide H**. Distribute *Blocking Air Investigation* and have students put it in their science notebooks. Remind students that in the Broken Things unit, we identified independent and dependent variables in order to design investigations. Have students turn and talk about the difference between these two variables. Then ask for a volunteer to remind the class what the difference is between these variables before having students fill in the table on *Blocking Air Investigation*.

Additional Guidance

Use the following to guide a discussion of variables:

Ask students to review the descriptions of independent and dependent variables on the handout quietly on their own and to fill in the last column for those rows of the table. Then prompt, *The independent variable is the change we make to the system. Where in our hypothesis can we find the independent variable?*

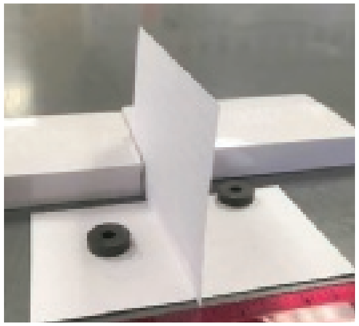
Have students look back at the consensus hypotheses that they recorded in *Framing Hypotheses* and that you recorded at the front of the room. Look for students to point to the second column of the Consensus Hypotheses Table on *Framing Hypotheses*, under the heading "Change to the system (cause)." Say, *Make a note of this on the Consensus Hypotheses Table by writing "independent variable" next to that column.*

Then prompt, *The dependent variable is the effect we want to observe. Where in our hypothesis can we find the dependent variable?* Look for students to point to the third column of the Consensus Hypotheses Table on *Framing Hypotheses*, under the heading "Effect on the system." Say, *Make a note of this on your hypothesis by writing "dependent variable" next to that column.*

Then say, *If we want to make sure that the effect we observe is in fact due to the change we made and not some change that was accidentally happening at the same time, we need to have controlled variables. In this case, we want to know about the* *air in between the two magnets, not, for example, the distance between the two magnets. What can we do to control for the distance variable? Turn and talk to a partner.*

After 30 seconds, elicit some ideas. Highlight student ideas about always keeping the magnets the same distance apart. Then say, *We will need to keep this in mind during the experiments. Remind me to check that the magnets are always the same distance apart*.

Conduct the first whole-class investigation. Gather the class around a central lab demonstration table or use a document camera to conduct the first investigation as a demonstration.



To conduct the investigation, place a note card in between two magnets to demonstrate that attractive and repulsive forces still exist between magnets. You can do this by keeping both magnets stationary at first and then releasing one of the magnets so that it will move towards or away from the note card. Repeat the process with a thicker object like a piece of cardboard. Recruit a student volunteer as an extra set of hands if needed.

Use chart paper to record findings as a class from this investigation and have students copy the findings onto *Blocking Air Investigation* as follows:

Object between magnets	Effect on energy transfer through magnetic forces
Note card	none
Piece of cardboard	none
(Any other objects used)	none

Display **slide I** and lead a discussion with the class to interpret and critique the results of investigation part 1.

Suggested prompts	Sample student responses
Do our results support the idea that air is involved in magnetic interactions, or do our results support the idea that air is not involved? Explain your reasoning.	*Our results suggest that air is not involved. Placing various objects between two magnets did not change the forces or energy transfer. Even if air is blocked by a note card or another object and air particles cannot collide with other air particles, the magnetic forces still occur, so energy transfer must still occur.*
So does this suggest that magnetic forces work like sound works or that they work differently?	*This suggests that magnetic forces work differently than sound. Magnetic forces don't require air.*
Does anyone still think that air might be involved in the forces between two magnets? Can anyone argue that our results from this investigation give us 100 percent certainty that air is not involved in the forces between magnets?	*We know that sound can travel through media other than air, including walls and other solid objects. And though we sometimes feel sound waves moving through solids, we don't usually see this happening. Maybe a compressional wave is moving through the note card and other objects, but we just can't see it.*

Suggested prompts	Sample student responses
Did anyone see or feel something today that might have been air interacting with the objects? Is it possible that air was still involved in the magnetic forces?	*Yes! We did see (or feel) the note card (or cardboard or other object) move a little bit when the magnets were near it.* *No, we only saw and felt the note card move when the magnets touched it.*
How can we remove the air altogether and see if that affects the behavior of the magnets?	*outer space* *a vacuum chamber*

Conduct the second whole-class investigation. Say, *It seems like we need more evidence to support our claim that air is not involved in energy transfer through magnetic forces, and I think a vacuum chamber might help us. I have a video that will help us collect some additional evidence.*

Use **slide J** to identify for the students what observations they should record after you play the Vacuum Chamber video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Students should consider these questions:

- What happens to the music in a vacuum?
- What happens to the magnetic forces in a vacuum?

Say, *Watch the video carefully. I'll play it at least two times. As you watch the video, record your key observations in your notebook*. Have students label the notebook page "Removing the Air." Play the video twice.

4. Making Sense and Home Learning

5 MIN

Materials: None

Making sense of the investigations. After playing the video twice, point to the posted consensus hypotheses that the class developed. Display **slide K**. Ask, *Did we observe either of these cause-and-effect relationships in the demonstration or the video? Turn and talk to a partner.* After a couple of moments, ask students to share out. Look for students to point out that neither cause-and-effect relationship held true and then cross off both of the posted hypotheses. Display **slide L** and assign home learning.

Home Learning Opportunity

Ask students to construct an explanation based on the investigations we did in class today, using *Writing an Explanation*.

Write a scientific explanation that answers the question, "Why did the music and magnets behave this way in the vacuum?"

*** Supporting Students in Engaging in Argument from Evidence**

Students should draw on their previous experience to complete this task. Argumentation is a focal practice in Unit 8.2, *Sound*. Look for students to 1) make a claim about how air is not involved in energy transfer, 2) provide evidence from either or both investigations, and 3) connect the evidence to the claim explicitly by explaining why it supports or does not support

Include

- **a claim** that answers the question,
- **evidence** from the video or other investigations, and
- **reasoning** that justifies why your evidence supports your claim.

They can write their explanation on the handout at home and then paste the handout into their notebooks the next time they are in class, or you can ask them to bring home their notebooks to write their explanations. If the latter, make sure to send the handout home with them or have students copy the directions from the slide into their notebooks. This is also an assessment opportunity, but keep in mind that SEP6: Constructing Explanations is not a focal practice for this unit. Look for students to:

- make a claim about how air is not involved in energy transfer.
- provide evidence from either or both investigations.
- connect the evidence to the claim explicitly by explaining why the data supports or does not support the hypothesis that air is involved in energy transfer.

5. Navigation — 5 MIN

Materials: None

Motivate a closer look at the space around a magnet. Ask, *What have we figured out about how energy is transferred?* Solicit 2-3 students to share their interpretations of what we figured out.

Then say, *We figured out that there are forces and energy transfer between magnets in completely empty space. That is not like what we saw in the Sound unit or the Broken Things unit at all! What could be happening in the space between the magnets if energy is* <u>not</u> *transferring through air?* Display **slide M** and say, *Talk with a partner about how we might be able to collect evidence to help us understand what is going on in that space between two magnets.*

After 2-3 minutes say, *I heard a lot of great ideas just now. In our next lesson let's plan to pursue some different ways we might be able to visualize the space around a magnet.*

the hypothesis that air is involved in energy transfer. If students are struggling to connect a claim to evidence from the investigations, at the start of the next lesson ask students to work in pairs to critique each other's explanations and then revise their own. If there is time, consider having students work in groups of three to develop a consensus explanation and share them as a gallery walk, allowing students to leave their critiques with sticky notes on chart paper. Pair or group students strategically, putting students with strong explanations together with students who need more support.

LESSON 4

What can we figure out about the invisible space around a magnet?

Previous Lesson

We wrote two hypotheses to predict the cause-and-effect relationships we would observe if energy transferred between magnets through the air. We used evidence from two whole-class investigations to show that these hypotheses were false. We weren't sure what was going on in the space between two magnets and wanted to investigate more.

This Lesson

INVESTIGATION

4 DAYS

We figure out that the space around a magnet is called a magnetic field. We decide to investigate the field with test objects, like iron filings and compasses. We investigate what the magnetic field looks like with iron filings and compasses and figure out that the forces in the field have a direction. We take compasses home and document the places in our lives where we find magnetic fields, including many electrical devices. We also figure out that the magnetic field around an electromagnet is similar to the field around a bar magnet. Finally, we use a computer interactive to help us visualize and model the magnetic field around a single magnet. We are wondering—what happens to the magnetic field when we add a second magnet?

Next Lesson

We will use a computer interactive to map the magnetic field around a magnet and a coil of wire in four different configurations. This will lead us to wonder—How might the changes we see in the simulated magnetic field due to changes in distance change the behavior of the magnets in real life?

Building Toward NGSS

MS-PS2-3, MS-PS2-5

What Students Will Do

Ask questions about the cause and effect relationships that produce the patterns we observed (and will observe) in the direction or size of forces in a magnetic field around a permanent magnet as it interacts with another object(s) near it.

Use diagrams and simulations to model the patterns we observe in the forces experienced by test objects placed near a magnet or a coil of wire connected to a battery (magnetic fields).

What Students Will Figure Out

- The space around a magnet has a particular 3-dimensional shape, which we call a *magnetic field*.
- Test objects, like small bits of iron and compasses, are affected by the magnet if placed inside the magnetic field.

- Test objects show us that the magnetic field is not the same in every location around the magnet and seems to weaken and disappear as you move farther away from the magnet.
- Electromagnets also have a magnetic field, and if the wire is made into a coil, the magnetic field is similar to that of a bar magnet.
- Forces in the field have a direction.
- The direction of the force is out of or away from the north pole and into or toward the south pole.

Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	12 min	**NAVIGATION** Set the stage for the investigation by connecting to the previous lesson and giving student groups a bar magnet and a disk magnet. They “feel” the space around the magnets when they bring like poles together. It feels different when they bring unlike poles together.	A-B	1 bar magnet, 1 disk magnet
2	15 min	**INVESTIGATE THE FIELD AROUND A MAGNET** Do a demonstration with iron filings and a bar magnet for students to visualize the magnetic field.	C-D	1 shaker of iron filings, 1 clear plastic tray, 1 bar magnet in a clear plastic bag, 1 piece of white copy paper, 1 three-dimensional magnetic field demonstrator (optional), 1-1L clear plastic soda bottle with labels removed (optional), 1L mineral oil (optional), computer and projector to show this video: 3D Magnetic Field Viewer - Unit 8.3 Forces at a Distance Lesson 4 (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Investigating the Field Around a Magnet
3	12 min	**MAKING SENSE OF MAGNETIC FIELDS** Students share their observations from the investigation in a class discussion and begin a working definition of magnetic field.	E-F	
4	11 min	**NAVIGATION** Students are engaged in a discussion of new questions about fields to focus them on categories of questions related to directionality and magnitude of the field.	G	2 or more index cards, marker, 1 bag of items tested from Lesson 2

End of day 1

Part	Duration	Summary	Slide	Materials
5	5 min	**NAVIGATION** The class recalls the main categories of questions about fields and records one of those categories as the lesson question.	H	sticky notes
6	5 min	**ORIENTATION AND PREDICTIONS** The class makes predictions about how the orientation of a compass needle would compare at different locations in the field around a permanent bar magnet.	I-K	
7	15 min	**TESTING THE FIELD** Students use compasses to determine that the forces in a field around a permanent magnet have direction that goes out of the north pole of the magnet and into the south pole of the magnet. The students represent these forces around a magnet as they draw the field and indicate the direction of the force.	L-M	Testing the Field
8	10 min	**MAKING SENSE OF OBSERVATIONS** Students record their responses to making-sense questions and then share their results with the class.	O-P	
9	10 min	**NAVIGATION** Students summarize what they learned and then consider if other objects besides magnets have a field. Students take a compass home to test objects at home and document what they find.	Q	Magnetic Fields at Home
				End of day 2
10	12 min	**SHARING OUR HOME LEARNING** Highlight key ideas we learned from the previous class. Record a list of objects or devices that students found had a magnetic field and ones that they did not. Motivate the need to test the electromagnet.	R-S	
11	20 min	**TESTING THE ELECTROMAGNET** Students see that there is a magnetic field around a coil and battery system and that forces in this field also have a direction. Students add to their working definition of a magnetic field based on what they have learned.	T-V	Testing for a Field Around a Coil
12	10 min	**REVISING OUR WORKING DEFINITION OF MAGNETIC FIELD** Have students add to their working definition of a magnetic field to include ideas about direction.	W	

Part	Duration	Summary	Slide	Materials
13	2 min	**NAVIGATION** Motivate the need to see more details of the magnetic field by asking students how they might get more evidence.	X	
				End of day 3
14	4 min	**NAVIGATION** Share ideas about how to figure out more about a magnetic field and introduce the interactive.	Y	Computer
15	20 min	**USE A COMPUTER INTERACTIVE TO MODEL THE FIELD** Explore details of a magnetic field to learn about how the field changes around a magnet or a coil and at a distance away from the magnet or coil.		Investigating the Details of a Magnetic Field
16	10 min	**ADD TO THE PROGRESS TRACKER** Add to the Progress Tracker with new information from the interactive and ways to represent the field around magnets and coils.	Z	
17	10 min	**NAVIGATION AND EXIT TICKET** Consider magnetic fields and how they would respond if another magnet was brought into the field.	AA-DD	scrap paper for exit ticket, *Reading: Finding the Way* (optional)
				End of day 4
		SCIENCE LITERACY ROUTINE		Student Reader Collection 2: *Beyond Magnets*

Lesson 4 • Materials List

	per student	per group	per class
Investigating the Field Around a Magnet materials			
Testing the Field materials		• 1 bar magnet • 5 compasses • 8.5″ × 11″ white paper	
Magnetic Fields at Home materials	• 1 compass		

Testing for a Field Around a Coil materials		• D-cell battery • coil of 18 gauge wire • 4 or more compasses • 8.5″ × 11″ white paper	• Optional: 1 25-50 cm piece of 18 gauge copper wire • half of a clear plastic clamshell container (see picture) • 2 D-cell batteries • 5 compasses • tape • coil of wire from a class speaker
Investigating the Details of a Magnetic Field materials	• tablet or computer		
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • scrap paper for exit ticket • *Reading: Finding the Way* (optional)	• 1 bar magnet • 1 disk magnet • 2 or more index cards • marker • computer	• 1 shaker of iron filings • 1 clear plastic tray • 1 bar magnet in a clear plastic bag • 1 piece of white copy paper • 1 three-dimensional magnetic field demonstrator (optional) • 1-1L clear plastic soda bottle with labels removed (optional) • 1L mineral oil (optional) • computer and projector to show this video: 3D Magnetic Field Viewer - Unit 8.3 Forces at a Distance Lesson 4 (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 1 bag of items tested from Lesson 2 • sticky notes

Materials preparation (20 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

For this lesson, it is important for you to read through the *Teacher Guide* carefully and note the amount of time needed for each activity. The time for this lesson may run long and the lesson may take longer than 4 days if your class does not move through the activities in the amount of time suggested. You may want to slow parts of the lesson down and spend more time on certain activities. Use your professional judgement to determine the appropriate pacing for your students.

Test the Lesson 4 version of the computer interactive on the computers that students will be using. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

- Iron filings stuck on magnets are difficult to remove. To keep iron filings from sticking to your magnets, and to make lab preparation and clean up easy, put each bar magnet into a clear plastic bag.

- Cut the clear plastic containers in half, separating the lid and the base. This will provide two trays. These trays will hold the iron filings and make clean up easier.
- Gather your materials for the demonstration on the first day. You will need these materials:
  - 1 bar magnet in a plastic bag
  - 1 shaker of iron filings
  - 1 piece of white printer paper
  - 1 clear plastic tray

Note: Keep the magnet in the plastic bag at all times.

- Work through the procedures in the investigation, Investigating the Field Around a Magnet, prior to class. Watch the video of the demonstration to help you prepare. Notice the technique that works best to see the magnetic field lines around the magnet. We suggest that you sprinkle the iron filings into the tray evenly around the magnet and then hold the plastic tray with one hand while gently tapping it on the opposite side with a finger of the other hand. This will help the iron filings move over the surface of the tray and line up with the magnetic field. You may have to repeat this process to get the desired effect. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- An optional activity is to make a homemade 3-D magnetic field viewer. If you want to do this, follow the directions in the instructions in *Do-It-Yourself 3-D Magnetic Field Viewer.*

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

In previous lessons, students figured out that certain objects (most containing iron) are attracted to a magnet. They also discovered that a coil of wire acts like a magnet when it is connected to a battery (an electromagnet). What happens in the space between two magnets seems to be an important piece in understanding how a speaker works. In this lesson students investigate this space and figure out that it is a magnetic field that surrounds a magnet and a coil. They figure out through investigation that the magnetic field produces a force that acts on certain objects. The direction of the force is out of or away from the north pole of a magnet and into or toward the south pole of a magnet. Students also discover that the electromagnet has a magnetic field very similar to that of a bar magnet.

Students should ask questions that would be possible and feasible to test in class so that they could figure out more about magnetic fields. These questions are often "how" or "why" questions, but there are exceptions. Some questions—like How is the magnetic field different on the two ends of the magnet? How does the magnetic field make objects like a compass needle move? or What causes the forces I feel when I put two magnets together?—are questions we will investigate in this unit. Other questions—like Do magnetic fields cause health issues? or What causes a magnet to be a magnet?—are beyond the scope of this lesson or are not testable in the classroom.

Where We Are NOT Going

Students start thinking about where the energy comes from that is transferred by the forces in a magnetic field, but they do not understand this idea yet. Sketched magnetic field lines, a visual tool to help us communicate about a magnetic field, are not introduced in this lesson or unit. However, students may come up with this representation on their own.

1. Navigation

12 MIN

Materials: science notebook, 1 bar magnet, 1 disk magnet

Review what we know about the space around a magnet. Ask students to recap what they have learned about the space around the magnet. As students share in a short discussion like shown below, highlight key ideas by writing them on the board.

These are the key ideas that should surface:

- There are repulsive forces (pushes) when similar ends of two magnets are near each other.
- There are attractive forces (pulls) when different ends of two magnets are near each other.
- Magnets attract objects with iron in them and do not attract other objects.
- Magnets do not have to touch objects to interact with them. But the objects have to come close to the magnet.
- Some objects experience a force when near a magnet.

Suggested prompt	Sample student responses	Follow-up questions
What have we figured out about the space around a magnet?	*Something is different about the space on one end of the magnet compared to the other end.*	*Why do you think that?* *What is your evidence for that?* *How do you know?*
	It seems to affect some objects and not others.	*Can you give me an example of something that would be affected by the space around a magnet?* *Can you give me an example of something that would not be affected by the space around a magnet?*
	It affects objects without the object having to come in contact with the magnet.	*Is this true for all objects?*
	It seems that there is a force on some objects when they are close to the magnet.	*You said "force"; what made you say there is a force?* *What do you know about forces?*

Highlight forces when they come up. If students do not mention "forces" in this discussion, ask additional questions around forces such as these:

- Some objects move toward the magnet and some move away. What starts the object to move?
- What can you use from previous units that seems important to what you are experiencing with magnets?

Motivate the new lesson question. Connect what students have figured out to what they still have questions about and are wondering about.

Say, *OK, though we know a lot about what the magnet interacts with and can describe it somewhat using ideas related to forces, it was strange that nothing needs to be touching when these things happen. And even stranger, we found that it even happens through empty space—even when there is no matter in that space between things interacting with a magnet or magnets. So what exactly is happening in that space? Let's try to figure out more about that.*

Give each pair of students a bar magnet and a disk magnet. Display **slide A**. Have students prepare their notebooks for a new lesson by writing the lesson number and the lesson question on a clean page.

Say, *We know that matter isn't needed in the space around the magnet to make it interact with other things. And, we cannot see what is going on in that space. Let's try to picture with our mind's eye—imagine—what is going on in that space. To do that, it may be helpful to close our eyes during the next investigation as we move one magnet around another and describe how we are picturing what is happening in that space around the magnets.*

Encourage students to try to feel or picture this space around the magnet by using the two magnets. Everyone in the team should have the opportunity to manipulate the magnets. If you have enough supplies, give a set of magnets to each student. Students may describe feeling a "bubble" around the magnets when they have like poles near each other.

Emphasize that picturing the forces that act on an object like a magnet at different locations around a magnet is a useful way to start visualizing what the space is that is "felt" around a magnet.

Ask students to share what they noticed. Students should say things like this:

- They found that the space around the magnets felt different depending on which side of the magnet they were investigating.
- They also should note that the space is not the same at all points around the magnet.
- Students may note that the forces they feel are not as strong the farther the two magnets are separated.

Ask students to describe how they picture or visualize what is going on in the space around the magnets that they are feeling. Accept all responses.

Acknowledge that we have some different ways we are picturing what is happening in the space around the magnet. Say that trying to picture this sort of thing is something that scientists have found useful to do too. They have a way to refer to what they are trying to visualize.

Introduce the term *magnetic field*. Show **slide B** to introduce students to the term *magnetic field* and add this phrase to the word wall or vocabulary tool you use in your classroom. Students should also write this term in their notebook under the lesson question. You do not need to have students write a definition yet—they will develop a working definition after they have investigated the magnetic field.

Say, *What we're trying to visualize around a magnet is sometimes referred to as a magnetic field.* Tell students that a magnetic field is the space around a magnet that we are trying to figure out.

Additional Guidance

Give students the term *magnetic field* now so that they have shared vocabulary throughout the investigation to refer to this invisible space around the magnet where forces from the field act on certain objects. Students will earn a more sophisticated understanding of what this word refers to as the lesson goes on. They will add to and refine their definition as they learn more about the field in this lesson and in lessons to come.

Say, *Let's work on developing some other ways to visualize this space—the magnetic field. Let's use our experiences with how magnets interact with things made of iron to try to visualize that space around the magnet. What if we had thousands of tiny pieces of iron and put them near a magnet in the space we are wondering about? What do you think would happen?*

Let a few students respond and then continue by saying, *I happen to have thousands of really tiny pieces of iron we can use to actually do something like this and see what happens. Let's try this out and see if it helps us learn more about magnetic fields.*

2. Investigate the field around a magnet.

15 MIN

Materials: Investigating the Field Around a Magnet, science notebook, 1 shaker of iron filings, 1 clear plastic tray, 1 bar magnet in a clear plastic bag, 1 piece of white copy paper, 1 three-dimensional magnetic field demonstrator (optional), 1-1L clear plastic soda bottle with labels removed (optional), 1L mineral oil (optional), computer and projector to show this video: Lesson 4 3D Magnetic Field Viewer - Unit 8.3 Forces at a Distance Lesson 4 (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Alternate Activity

This activity is a teacher demonstration, but if you have extra time and supplies, you may choose to do this as an investigation with small groups of students. If you do, you will need a lot more time for the activity.

Set the stage for the demonstration. Display **slide C** to orient students to the demonstration with a magnet and iron filings.

- Read the first question (What sort of things might these iron filings do if we brought a magnet close to them?) and ask students for ideas. Accept all responses (e.g., some filings might be attracted to the magnet, some might stick to the magnet, and some that are too far from the magnet might do nothing).
- Read the second question (How could the iron filings help us determine where the magnetic field is located around the magnet?) and ask for connections. Students should say that the locations where the iron filings respond to the magnet indicate that they are seeing spots located within the magnetic field.

Prepare to investigate the space around a magnet. Display **slide D**. Ask students to find a new two-page spread in their notebooks and record the lesson question at the top: What can we figure out about the invisible space around a magnet? Underneath, on the left page, students should write "Observations of the magnetic field." On the right page, students should write "Questions about the magnetic field." Tell students to sketch what they see as they participate in the demonstration. If students have questions about what they are observing, encourage them to record their questions in their notebooks.

*** Supporting Students in Developing and Using Patterns**

As students look for the shapes that iron filings are making around the magnet, they are recognizing patterns in the way iron filings respond to magnetic fields. Point this out for students. Say, *Patterns may show up in numerical data that we collect in an experiment, but visual patterns are also important for scientists. These kinds of patterns can give us clues about invisible interactions.*

Students will be asked to look for patterns several times in this lesson. Emphasizing this practice early in the lesson will help establish the practice as a consistent way for students to learn more about magnetic fields.

Tell students to sketch a bar magnet on the Observations page and to leave space all around the magnet to add their observations to their drawing. Tell them that during the demonstration they should look for how the filings behave and any patterns they see developing in the way the filings move around the magnet.* Encourage students to add labels and annotations to their sketches now and when they make observations of the iron filings.

Begin the demonstration. When their notebooks are ready, ask for volunteers to help with the demonstration. Ask the volunteers to help with setup, sprinkle iron filings (with your guidance), and adjust the document camera. Gather students around a central desk or project the demonstration using a document camera. All students should be able to see. If this is impossible, repeat the demonstration with students who are unable to see in the first demonstration.

Once students are in place and before you begin the demonstration, remind them of the purpose of this investigation, which is to use iron filings to help visualize the magnetic field around a magnet.

Steps for the demonstration

1. Arrange your supplies so that the magnet is on top of the white paper. Lay the clear plastic tray away from the magnet.
2. Sprinkle iron filings in the tray evenly, making only a thin layer of filings. Have students notice the arrangement of the filings. They should not draw this now.
3. Carefully lift the plastic tray without disturbing the iron filings. Move it over the top of the magnet, keeping it about a foot above the magnet. The filings should not be interacting with the magnet at this point.
4. Gently lower the plastic tray straight onto the magnet. Students should see the iron filings respond to the magnet.
5. Gently tap on the edge of the plastic container while holding it secure with your other hand. This will help the iron filings have a more significant response to the magnetic field.

Additional Guidance

If you don't sprinkle the filings evenly in the tray, the filings may just clump near the ends of the magnet. In this case, tapping the side of the plastic tray will not do any good. It may be necessary for you to pick up the plastic tray, pour the filings back into the shaker, and start over. Then, sprinkle the filings evenly and lightly over the entire bottom of the tray in order to see the magnetic field lines better. Once the tray is over the magnet, hold the tray with one hand and gently tap on the opposite side of the tray with a finger of the other hand. This will help the iron filings move and respond to the magnetic field.

Lead an ongoing discussion during the demonstration. As students are observing the behavior of iron filings around a bar magnet, encourage them to record what they observe in their notebooks. Prompt them to look for patterns. As they record the results of the investigation, they should also record new questions this investigation raises for them on the page next to their observations labeled "Questions about the magnetic field."

Suggested prompts	Sample student responses	Follow-up questions
What are you figuring out with these iron filings?	*It seems the pattern of filings around the magnet is different at different places on the magnet.*	*Say more about how the pattern is different.*
	I think the field is three dimensional because I see some iron filings sticking up from the paper.	*Can you think of a way we could test your idea?*
	The iron filings move and seem to line up in a pattern around the magnet.	*What causes the iron filings to move? (This is an important point to bring out. Continue probing this line of thinking until students acknowledge that a force must have caused the iron filings to move.)*
Are the patterns you see the same at each end of the bar magnet?	*Yes they are.* *Wait, a magnet is different at each end because another magnet behaves differently depending on which end it is near. So why do the patterns look the same?*	*Did you put something about the difference at each end of the magnet as a question you have?* *How do you think we could learn more about how the field might be different?*
What have you learned about forces and energy in past units?	*Forces transfer energy between objects.* *But, the objects we were using before were touching—these aren't.*	*Do you think there is still energy transfer between the magnet and the iron filings even if they are not touching?*
Where do you think the force is coming from?	*the magnet* *The field around the magnet.*	*Do the iron filings have to come into contact with the magnet or touch the magnet to experience a force?*
Do you think the force is the same at all points around the magnet?	*no* *yes*	*Why do you think that way?* *What is your evidence?*
*What new questions do you have about magnets or this space around a magnet that we don't quite understand?**	*I wonder if the space could somehow be transferring energy.* *I wonder if the magnet is making some kind of invisible force bubble around itself.*	*How could we test this?* *Can you put that into a question that would give us more evidence?* *What could you figure out by testing this?* *What would be your process for testing this?* *Can you reword this into a question?*

* Supporting Students in Engaging in Asking Questions and Defining Problems

Help students develop testable questions by asking them to consider how the answers to their questions will help move us forward. Their questions should help us figure out more about our model. Encourage them to consider questions that we can test in the classroom and those that require us to gather more evidence to make our model more complete or accurate. Discuss their observations by using the prompts above.

* Supporting Students in Three-Dimensional Learning

Emphasizing cause and effect and calling the students' attention to this crosscutting concept while they are collecting observational data from a demonstration to understand more about magnetic fields is a three-dimensional teaching and learning opportunity.

Allow time to record observations, sketches, and questions. As students are adding to their notebooks, take a photo of the results of the demonstration for reference later and put away the materials from the demonstration. Remind students to record in their notebooks any new questions they have.

Find evidence that the field extends into three-dimensional space. Some students may have observed the iron filings standing up in the tray, which caused them to realize that the field around the magnet is three dimensional. If it did not come up, call students' attention to the iron filings again and how they stand up around the ends of the magnet.

Pose the question, *What do you think it means that the filings stand up?* If you have one available or have made the 3-D Magnetic Field Viewer, show students a three-dimensional demonstration for a magnetic field. You may want to show this video to demonstrate a three-dimensional magnetic field. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Also included with this lesson is a teacher reference sheet (*Do-It-Yourself 3-D Magnetic Field Viewer*) with instructions for making a homemade three-dimensional magnetic field viewer. Ask the students what evidence they can get from this demonstration (or video) to help them understand that magnetic forces extend into space above, below, and around the sides of a magnet.*

3. Making Sense of Magnetic Fields

12 MIN

Materials: science notebook

Conduct a Building Understanding Discussion to make sense of their investigation. Display **slide E**.* Ask a student to describe one observation they made during the demonstration. Ask if another student found something similar to the first student, also ask if someone found something different. Continue eliciting additional observations made by different students. As students share, probe their ideas by asking if any one found something *different from or in addition to* what has already been shared.*

Key Ideas

Purpose of this discussion: The purpose of this discussion is to make public the key ideas students discovered during their investigation of the space around a magnet using iron filings and to prepare them for developing a working definition of magnetic fields.

Look for these ideas:

- The iron filings moved around the magnet.
- The iron filings seemed to line up around the magnet.
- There appeared to be more filings around the ends of the magnet compared to the middle of the magnet.
- The shape of the field around the magnet didn't seem to be the same at the ends of the magnet as it was in the middle of the magnet.
- The magnetic field is three dimensional.

Synthesize and summarize what we have figured out. Have students synthesize their ideas in a working definition of *magnetic field* by first giving them a few minutes to record in their notebooks what they figured out about magnetic fields. Tell students to add labels to their sketches and add other text to describe what they figured out in the investigation.

*** Strategies for This Building Understandings Discussion**

As students share their observations, use prompts to get students to explain these observations with science ideas they already know. For example, when students share their observations about the movement of iron filings, follow up with a question that gets them thinking about magnetic forces, such as these:

- What is your evidence for a force in the field?
- What caused the iron filings to move?
- Why do you think the force acted differently closer to or further away from the magnet?
- Do all objects in the field experience a force?
- Do you think energy is transferred? What is your evidence?

Develop a working definition of *magnetic field*. Ask students to share ideas they recorded about what they know about the field. Record their ideas on the board (see sample prompts and responses below). Examples of ideas that students should have about the magnetic field include the following:

- It is the space around the magnet.
- It affects the behavior of certain objects, and these objects move, so the objects must experience a force.
- Energy is transferred to make the iron filings move.
- Forces cause the iron filings to line up in a certain way.

Other ideas that may come out are that

- the space is three dimensional and
- the force that objects experience is not the same at every point around the magnet.

Once these ideas come up in discussion students can use them to write a working definition.

Suggested prompts	Sample student responses	Follow-up questions
What do you know about the space around a magnet?	*It extends out from the magnet in all directions.*	*What is your evidence for that?*
	It is three dimensional.	*What patterns did you notice to help you figure this out?*
	It isn't as strong farther away from the magnet.	*How do you know that?*
	We call the space the magnetic field.	
I heard some of you talk about forces and energy. Should we include force as part of our definition?	*yeah*	*How do you know there is a force in the field?*
Does the field mean there is a force around it—like a force field?	*yes*	*If so, would all objects feel the force?*
What would happen if I put a wooden toothpick in the field?	*It would not feel a force.*	*So this force field only affects certain objects. What objects does it affect?*
How is energy involved in all of this?	*A force transfers energy, so energy is transferred somehow, but I am not really sure how this happens.*	*So, we may need to know more about magnetic fields. Let's record what we know now before we investigate more.*

Record a working definition of *magnetic field*. Display **slide F**. Allow students time to put their ideas together and write a definition in their notebooks. They should record it in their notebooks where they wrote the term *magnetic field* under the lesson question. Their definition should be similar to this: A *magnetic field* is a region of space around a magnet that appears to affect the behavior of certain objects. The objects experience a force when they are in the field.

* Supporting Students in Developing and Using Cause and Effect

This is an opportunity to help students recognize the cause-and-effect relationship between putting the iron filings in a magnetic field (cause) and the orientation of the iron filings (effect) and consider the mechanistic how or why explanations for this relationship. Use the language of cause and effect introduced in earlier lessons to point this out in order to make clear that these tools are crosscutting. For example, say, *When we sprinkle iron filings around a magnet then we will observe the iron filings align in patterns. How or why are the magnetic filings lining up that way?* Look for students to talk about force pairs at this point. Some students may mention the magnetic field as a mechanism.

* Supporting Students in Three-Dimensional Learning

You have the opportunity to formatively assess students on their ability to make sense of their observational data in all three dimensions. Scaffold this experience for students by emphasizing that they are analyzing observational data that reveal interesting patterns that are helping them to understand more about magnetic fields.

Have two or three students share their definitions. If you have a word wall, add "magnetic field" to it or use a vocabulary strategy that is familiar to your students. Continue to revisit the term as students build their understanding of magnetic fields during the next activities and lessons.*

4. Navigation

11 MIN

Materials: science notebook, 2 or more index cards, marker, 1 bag of items tested from Lesson 2

Add questions to the Driving Question Board. Display **slide G** and pass out at least 2 index cards and a marker to each group. Ask students to work with their group to write down one or two new questions (one per card) they had about magnetic fields during their investigation. These questions can come from those they recorded in their science notebooks. Encourage students to revise their questions if needed to ensure that they are testable in the classroom and will help us figure out more about our models and help us to explain the phenomenon better.

Remind students that asking questions about cause-and-effect relationships is a great way to organize their thinking. Use the following questions to help students develop questions about cause-and-effect relationships:

- What effect will we see if we make this change?
- What change do we need to make to get this effect?
- If we make this change, will we always get this effect?
- Why or how do we get this effect when we make this change?

Encourage students to word their questions in a way that is testable in the classroom. Give them examples of questions that fit this criteria. For example, the question "How does the magnetic field change when there is an attractive versus a repulsive force with two magnets?" is one we can investigate in our classroom. However, a question like "Do magnetic fields cause health issues?" is a valuable question to consider but not one we can investigate in the classroom.

Ask students to share the value of answering both example questions. Students should recognize that both questions are important and should be investigated. Guide them to recognize that developing questions that we can investigate in the classroom now will help move us forward in answering our questions.

Assessment Opportunity

This is an opportunity to assess students' ability to ask questions that are testable in the classroom. If students struggle with this task, offer them more examples and nonexamples as a means for them to compare the questions. Follow by asking them to offer their own examples and then analyze those questions with the students using criteria such as considering if

- the answer to the question will help us figure out an important part of our model or help us to explain the phenomenon better,
- the answer to the question is one which we can test in the classroom with the available equipment and time (follow with asking students for a summary of how we would conduct the test), and
- the question leads to gathering new evidence that will help us figure out more about our phenomenon.

Give each group time to share the question(s) they want to add to the Driving Question Board.

As students share, place their questions on the DQB and categorize them in anticipation of the remainder of this lesson. A likely category will be related to direction (e.g., questions about pushes versus pulls, the direction of the force at different locations in the field, or how the field "felt" different at the ends of a magnet). This is the category of questions important to identify. Work with students and get their input on the categorization and labeling of this category. If students don't pose questions in this category, prompt them by asking questions such as, *What do you wonder about the two ends of the magnet? Did you see any differences with the iron filings? What else could we use?*

Another likely category would be questions related to magnitude or strength (e.g., questions regarding patterns observed in the filings at the end of the magnets, observations of varying force strengths closer and further from the magnet, making the field stronger or weaker). It is OK if your students do not have questions in this category, but if they do, work with them to identify this as a category. There may be other questions that do not neatly fit into one of these two categories, which is OK. You can make an "Other" category.

Focus on directionality or using a magnet as a test object. In the last 2 minutes of class, focus students on the direction of magnetic forces. Encourage students to think about what they could use from the assortment of test objects familiar to them from Lesson 2 to identify the direction of forces that are exerted on objects in a field.

Suggested prompts	Sample student responses
Does what we learned from our investigation help us figure out why the field around a magnet feels different depending on which end of the magnet you bring near another magnet?	*Not really.* *We just know what a field looks like and what it is called. We don't know how it works to cause different kinds of forces.*
Let's look at all our test objects. What object could we use that will respond to a magnet that can also tell us something about what direction the forces might be acting in the field?	*a compass*

Additional Guidance

Students will likely not come up with a compass without seeing the sample of test objects from Lesson 2. Once displayed, ask them if there is any test object they have used before that might help them learn if the magnetic field has a direction. Students might not remember that the needle of the compass is actually a small, permanent magnet. Displaying these objects can help students focus on the compass more quickly.

Say, *We learned a lot about magnetic fields, but there are still some things we need to figure out. You suggested some questions that tell me you're wondering about direction of forces at different locations in the field and about the strength of the field in different locations. We decided we can use a compass to see if we can find out if a magnetic field has a direction. That will be our task for tomorrow.*

End of day 1

5. Navigation

5 MIN

Materials: science notebook, sticky notes

Lead a discussion to elicit the main categories of questions we had about fields. Remind students that they were able to visualize the effects of the magnetic field around a magnet using iron filings. This field affected the iron filings, and the iron filings moved because they experienced a force.

Display **slide H**. Ask students to recall the main category of questions we had from the last class that made us wonder about how the forces in the field might compare in different places in the space around a magnet. Students should recall that we had some questions about the direction of those forces.

Additional Guidance

As you are talking with the students in the next few lessons, be careful when you discuss direction and the magnetic field. The field itself does not have direction. The field tells us about forces on other magnets or magnetic objects in the field, and those forces have a direction. Being careful with the way you phrase questions and discussions will help students construct a scientifically accurate conceptual model for magnetic fields.

Say, *We want to eventually be able to answer all these questions, so let's tackle one of these categories today and the others a little later. Today, let us try to make progress on the category of questions we had related to directions of the forces in the field around a magnet.*

Additional Guidance

Place a sticky note on this first category as a visual milestone for where we are starting our work. Write "#1 Direction" on the sticky note. As you focus on additional categories in the unit, return to the DQB and mark those categories with sticky notes also.

Remember that this is still Lesson 4 and we are trying to answer the larger question, What can we figure out about the invisible space around a magnet? Now we will focus on figuring out if the forces have a direction and, if so, in what direction those forces act.

6. Orientation and Predictions

5 MIN

Materials: science notebook

Orient students to the system we will be exploring. Show **slide I**. Remind students what a compass needle is by reading the text at the top of the slide. Read the question at the bottom of the slide and tell students to turn and talk with a partner. Then have a few students share out. The red end of the compass needle shown is the north pole of the compass needle. We know if the compass was labeled on its red side to indicate that it is the same as the north end of a magnet, then it should behave the same way as a magnet. We should think about when we brought two magnets together with the stickers facing each other.

Introduce the terms *north pole* and *south pole*. Students will notice that many magnets are marked with an "N" on one end and an "S" on the other end. Ask if anyone knows what those letters stands for. Several students may be familiar with the terms *north pole* and *south pole* when referring to magnets. Tell students that we will use this convention to keep track of which end of the magnet we are referring to. Students may make the connection to the North and South Poles of Earth. They may also know that Earth has a magnetic field and this field makes compass needles point toward the north.

Display **slide J**. Ask students, *Why is it important to keep track of which end of the magnet is which?* Have students discuss this question as a Turn and Talk. This is an opportunity for students to make the connection to what they found out in Lesson 2 about how the orientation of the magnet impacts attraction and repulsion. Ask students to share out. Use probing questions to clarify student thinking around terms like *flipping*, *sides*, *ends*, and so forth. Then say, *In Lesson 2, when we put stickers on one side of the permanent magnet and on one side of the electromagnet, we were essentially labeling the ends of the magnet so that we wouldn't forget which was which. This was important because when the stickers were facing each other, the magnets repelled, or pushed apart, but when one sticker was facing in and one was facing out, the magnets attracted, or pulled together. From now on, we can use "north pole" and "south pole" so that we know when the magnets will attract each other and when they will repel each other. One way to say this is that "similar poles repel each other."*

Suggested prompt	Sample student response
What should the red end of the compass needle do when it is brought near the north end of a magnet—repel or attract?	*They should push away from each other—they should repel.*

Make and share some initial predictions with the class. Show **slide K** and read the question on the slide. Point out that the diagram below the question shows the N end of the compass needle as a red arrow in Location A. In this diagram, the needle is a small, permanent magnet pointed to the left. The diagram does not show which way the needle would be facing if we moved the magnet to locations B, C, D, and E. Read the question again and then direct students to record predictions in their notebooks by drawing which direction they think the needle will face at each location shown (B, C, D, and E). Give students a minute to record their predictions.

Ask students to share their predictions for these locations. Try to get from students several different predictions and different reasons for those predictions. Generating some controversy will help further motivate the need to investigate the lesson question.

7. Testing the Field

15 MIN

Materials: Testing the Field, science notebook

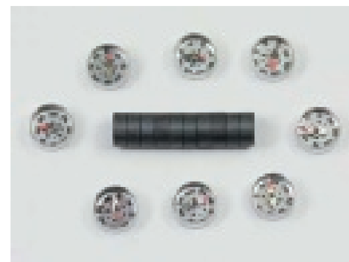
Get ready for the investigation. Display **slide L** and put students in groups of 3-4 for the investigation. Tell students they have only 15 minutes to complete their tests. Instruct them that they will use the compasses much like we did the iron filings. They should make sure that no other magnets, except for the one they are using for the test, are near their setup.

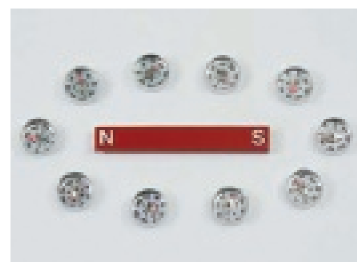
Remind students that the purpose of this investigation is to get evidence to answer the questions they had about whether the forces in the field have a direction. We know that some objects experience a force in the field and that forces have direction. One thing we were wondering is if the forces in the field have different directions in different places. We can predict that the forces will be either attractive or repulsive at least near the ends because we already have evidence for both attractive and repulsive forces when a magnet is close to the field at one end or the other end of another magnet, but where exactly that happens in the space around the magnet we don't know for sure.

Ask students, *What do you expect to see the compass needles do if the forces in the field have a direction?* Then ask, *What do you expect to see the compass needles do if the forces in the field don't have a direction?*

Remind students about using compasses. Remind students that compass needles are really small magnets with a north and south pole just like their bar magnet. They need to place the compasses around the magnet and move them to various places in the field. Remind students to draw sketches of what they observe when conducting their test with compasses. They will also need to let the compass needles come to rest before recording any data. Display **slide M** and let students begin their investigation.

Additional Guidance





Remind the students that the needles are permanent magnets. Therefore, if you put them too close together, they will respond to each other and not the bar magnet.

Consider testing a set of 10 disc magnets as an extra demonstration for your students. The magnet inside the speaker is a disc magnet, so testing the disc magnet can serve as a bridge between what students figure out about the bar magnet and what they are trying to explain in the speaker.

Steps of the investigation (also shown on **slide M** and in the student procedures):

1. Place your compasses all around your magnet.
2. In your notebook sketch the orientation of the compass needles at each location. There is no need to draw the whole compass.
3. Move the compasses to different locations around the magnet and sketch the orientation of the needle at each location.
4. Repeat this process until you have a map of the field around the magnet.

Monitor the investigation. As students work through the investigation, visit their groups, ask them about their observations, and probe their responses to find out more about what they are thinking. Students should discover that the forces in a magnetic field do have a direction and the compass needles will point away from the north pole of the magnet and toward the south pole of the magnet. Example questions and responses you may use as you visit groups are in the table below.

Suggested prompts	Sample student responses	Follow-up questions
Do your observations support or contradict your predictions?	*support* *contradict*	*What evidence do you have that supports (or contradicts) your prediction?*
If the compass needle is pointing in the same direction as the force of the bar magnet, how would you explain the direction of the force at the north end of your magnet?	*The compass needle always points away from the north end of the magnet because the force is pointing in that direction. The forces near the north pole of the bar magnet push away the north pole of the compass.*	*What does that tell you about the poles of the compass needle? (In the picture on slide L, the red end of the compass needle is the north pole and the silver end is the south pole.)*
Can you explain the direction of the force at the south pole of the magnet?	*It is like the force would pull the north pole of the compass needle toward the south pole of the bar magnet. So the direction must point toward the south pole.*	*How can you (did you) draw a representation of the directions that you have just explained?*

Additional Guidance

Allow students to represent the direction of the forces in a magnetic field in any way they choose for now. At the end of this lesson, the class will come to a consensus on how to represent the direction of the forces in the magnetic field. In this investigation, it is fine if they choose different ways to represent the direction of the force in the magnetic field.

Wrap up the investigation. In the last 3 minutes of the investigation have students finish their sketches. Display **slide N** and prompt students to start discussing the questions on the slide with their team as they complete their sketches.

8. Making Sense of Observations

10 MIN

Materials: science notebook

Add to the Progress Tracker. Display **slide O**. Give students a minute to add to their Progress Tracker any new ideas they figured out. Students should begin by recording the lesson question: *What can we figure out about the invisible space around a magnet?* They then record their ideas using any combination of words and pictures in the right column of the Tracker. Students might add these new ideas:

- The forces in the magnetic field have a direction.
- The direction of the force is away from the north pole and toward the south pole of a magnet.
- The ends of a magnet are called the north pole and south pole.

Display **slide P**. Have students individually record in their notebook their responses to the questions on the slide.*

Assessment Opportunity

Student responses in their notebooks are an opportunity to formatively assess students on their ability to recognize patterns in their data and describe the patterns of the compass needles. Students should use these patterns to describe the direction of the forces in the magnetic field. They use the same ability to describe the shape of the magnetic field around a magnet. Students should describe the direction as pointing out of the north pole of the magnet and into or toward the south pole of the magnet. They should describe the shape as extending all around the magnet in three-dimensional space.

If students are struggling to use the patterns to describe the shape of the field and the direction of the forces, work with these students using compasses and a magnet. Have students picture the compass needles as arrows and help them understand that the arrows point in the direction of the force. To reinforce this, have students hold the north end of a small magnet at each end of their bar magnet and note the direction that the small magnet moves in relation to the bar magnet. The north end of the small magnet should be pushed away from the north end of the bar magnet and pulled toward the south end of the bar magnet. This is the direction of the forces that are in the magnetic field.

If students fail to recognize that the field exists in three-dimensional space, sprinkle iron filings in the clear tray that is on top of a magnet. Have the students look at the magnet at eye level so that they can see the iron filings sticking up vertically off the plastic tray. Ask the students what they think that means. Follow up with a video or image from the internet of the three-dimensional space around a magnet.

Have students share their responses with the whole class. Use a dialogue like that shown below to elicit student ideas.

Suggested prompts	Sample student responses	Follow-up questions
How do the directions of the forces in the field around a magnet change?	*They change direction at different locations.*	*How did they change?* *How does the direction the compass needle points help you determine whether the forces in the field have changed direction?*
How would you describe the shape of the magnetic field around the magnet?	*The field points away from the north pole of the magnet on that side of the field and toward the south pole on the other side of the field. And it curves or bends away and around the sides of the magnet, following a loop.*	*What evidence did you see that the forces in the field were going one way near the poles but a different way along the sides of the magnet?*

*** Attending to Equity**
The time you allow students to think about these questions on their own will give them the opportunity to organize their thoughts. This is especially important for emergent multilingual students. They will have time to plan their responses individually before being asked to share their ideas with the class. This will help support greater participation from these students.

9. Navigation

10 MIN

Materials: Magnetic Fields at Home, science notebook

Navigate from the discussion to providing students the next steps in the lesson. Display **slide Q** and discuss the questions on the slide with students. Ask students to share ideas with the whole class. Students will likely say they can use a compass to see if it responds to different objects.

Suggested prompts	Sample student responses
Do you think permanent magnets are the only things that have fields?	*Electromagnets should too.*
What would you expect your compass needle to do if it was close to an object with a magnetic field?	*The compass needle would move.*
*What would you expect your compass to do if it was close to an object that does **not** have a magnetic field?*	*The compass needle would not move or would line up pointing north.*
Where do you think you will find magnetic fields in your own home?	*near electronic devices, near magnets, near my refrigerator*

Additional Guidance

Avoid bringing bar magnets or other powerful magnets close to electronic devices. They may damage the electronics in the equipment. Only use compass needles to detect magnetic fields around different objects in the room.

Also, do not be tempted to have students use a compass app on their cell phones. These apps use the GPS system of the phone and will always point toward the magnetic North Pole of Earth. The compass app will not be affected by magnetic fields in electrical devices or magnets.

Safety Precautions

Ask students why, for safety reasons, they should make sure to not actually touch any electronic device that is plugged in, nor the cord, nor the socket the cord is plugged into.

Establish that this is to ensure that they don't accidently get shocked by any faulty electrical wiring or sockets in their house. Remind them that by keeping the compass at a distance and not touching any of those things, they can safely explore whether there are magnetic fields in the space around the objects they select to explore.

Present the home learning activity: Testing for magnetic fields at home. Give each student a small compass to take home. Instruct students to take the compass home and put it near a variety of objects or devices they have there. If possible, ask students to photograph or take short videos of places in their home where they noticed a magnetic field and to bring the photographs or video clips of one of the most surprising places they found in to share with the class. They should also keep a list of objects or devices that they find to have a magnetic field and objects or devices that do not have a magnetic field.

Wrap up the lesson by summarizing what they have learned and establishing a foundation for learning more in the next class about the magnetic field in their homemade speaker.

End class by saying, *We have learned a lot about fields around magnets. As you leave today, share with your elbow partner at least one object or device at home that you plan to test with your compass and explain why.*

End of day 2

10. Sharing Our Home Learning

12 MIN

Materials: science notebook

Recap where you left off in the previous class. Remind students about their work from the class before. They used compasses to investigate the field around a magnet. Display **slide R**. Ask students to turn to their elbow partner to share what they learned from taking a compass home to find magnetic fields where they live.

Share what objects or devices have magnetic fields. Have students share what they discovered in their home learning experience. If you asked students to take photographs, consider collecting photographs digitally before class and making a slideshow. Ask students to describe what they found as their slide comes up. If you ask students to print photos, you can have them post them on a piece of chart paper at the front of the room. As students come up and post their photos, they should explain what they took a photo of and why. You can also make a two-column chart on the board or chart paper to list the results from students' tests.*

Ask, *What objects or devices did you find at home that gave evidence that they have a magnetic field?* Follow up responses by asking students where on the object or device they held the compass, if the device was turned on (if applicable), and what their evidence was that the object or device has a magnetic field. Continue until students have shared a good number of objects and devices.

Continue by asking, *What objects or devices did you find at home that do* not *give evidence of a magnetic field?* Follow up with the same type of questions as before until you have a list of several objects and devices.

Mark or highlight any electrical devices. Place a star beside or highlight any electrical devices that demonstrated that there is a magnetic field around it. Ask students, *What do all these devices have in common?* Students should recognize that they are all electrical devices or they may say that you plug each of these into the wall socket. Note if the device had a speaker or not and if the device was turned on or not.

Additional Guidance

Any device that has a speaker is one that will show a magnetic field since there is a magnet in the speaker. Students will also find magnetic fields around an electronic device that is powered on even if it doesn't have a speaker. They will also notice that devices that are not visibly "turned on" but are plugged in may show a magnetic field. Devices like a microwave and an oven have power running through them even if they are not "turned on". Students will see a magnetic field around these devices because of the small amount of electricity used to power the clock and other components that need a constant source of power. These devices may also have magnets in them.

*** Attending to Equity**

This is an example of self-documentation, an instructional routine that can be used to help students see how the focal science ideas they have learned about relate to everyday phenomena of their lives. This routine can be a powerful way to support students in forging connections between their identity outside of the classroom and the science ideas they engage with inside the classroom.

If you are concerned that some students will not have access to a camera but still want to give all students the opportunity to take photographs, consider collecting the images anonymously and adding them to a slideshow. Afterward, ask for a couple of volunteers who want to talk more about the photo they contributed, so as not to draw attention to those students who did not contribute photos.

Say, *We saw a lot of electrical devices that seem like they may have a magnetic field. That's really interesting. Is there anything in our speakers that might be electrical?* Look for students to suggest the electromagnet. Then say, *Maybe we should test the electromagnet to see if there is a field around it.* Display **slide S** and pose the question on the slide as a Turn and Talk: *What could we do to test if the electromagnet has a magnetic field?* Look for students to suggest using compasses or iron filings.

11. Testing the Electromagnet

20 MIN

Materials: Testing for a Field Around a Coil, science notebook

Motivate the need to know more about the field around an electromagnet. Show students the coil of wire from their speakers and also a coil of wire that is spread out and made from thicker wire. Ask students to describe similarities and differences in the two coils. Students should notice that the speaker coil is made of thinner wire and is scrunched together. Students should recognize that they are basically the same thing.

Say, *We will be using this bigger coil that is spread out and made from thicker wire in our investigation. But, it is basically the same thing as the coil we have in our speakers.*

Suggested prompts	Sample student responses
What have we figured out about our coil of wire?	*We know it acts like a magnet when it is connected to a battery.*
So do you think the coil has a magnetic field?	*yes* *But we don't know what it looks like.*
How could we find out?	*We could use iron filings or compasses around the coil.*
*What patterns do you expect to see with the compasses and coil?**	*Accept all answers.*

Say, *Let's use compasses to investigate the coil further.*

Have students make connections and make predictions before the investigation. Display **slide T**. Ask students to make predictions based on the questions on the slide. Have students predict how the needle in a compass will point at the locations of the question marks on the photo. They can draw their predictions in their notebooks and title their predictions "My Magnetic Field Predictions".

Test the magnetic field around a coil of wire. Display **slide U**. Encourage students to use arrows to indicate the direction that the compass needles are pointing and to sketch in their notebooks what they see. Also encourage students to put a compass in the center of the coil to observe what happens to the field at that position. Slide U has steps 1-4 of the instructions below. Pause students and check their setups before advancing the slide and before

*** Supporting Students in Developing and Using Patterns**

A magnetic field is essentially a name we give to a pattern we see in the behavior of magnetic objects when they are close to one another. Noticing that the iron filings are organized and that the compass needles align to trace the same invisible lines revealed by the filings is the first step for students in constructing and understanding fields and why they are useful for explaining phenomena. *A Framework for K-12 Science Education* (2012) states, "Noticing patterns is often a first step to organizing phenomena and asking scientific questions about why and how the patterns occur... Once patterns and variations have been noted, they lead to questions; scientists seek explanations for observed patterns and for the similarity and diversity within them" (p. 85-86).

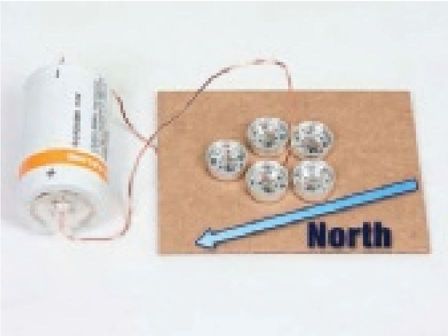
students continue testing their predictions. Students should not have both leads connected to the battery yet. As students finish with their setup and you have checked it, display **slide V**. Give students time to test their predictions about the magnetic field around a coil of wire.

Instructions

1. Lay the coil flat on your desktop.
2. Connect wire leads with alligator clips to the wires of the coil.
3. Connect one alligator clip to the battery.
4. Place small compasses around the coil. Be sure to place them along the coil and at the ends of the coil. Place one compass inside of the coil.
5. Sketch your arrangement in your notebook. Draw small circles for the compasses but do not draw the compass needles yet.
6. When everyone in the group is watching, touch the loose wire to the remaining terminal of the battery.
7. Draw arrows in the compasses to show the direction that the compass needles point when both ends of the coil are connected to the battery.

Alternate Activity

Students may wonder if the wire has to be coiled to have a magnetic field. You can test this out as a demonstration. Use the plastic clamshell container and punch a small hole in the center so you can run a straight piece of wire through it perpendicular to the surface of the container. Place five compasses around the wire as close to the wire as possible. Connect one terminal to one end of your wire. As students are observing, connect or touch the other wire to the other terminal. The compass needles will move and point either clockwise or counterclockwise around the wire depending on which wire goes to each terminal. Do not demonstrate that the direction changes when the terminals are switched. Students will discover this in a later lesson.



Students may also want to test their coils from the homemade speaker. Allow them to try this out, but because the wire is so thin, the resistance in the wire is high. This will result in the coil of wire and battery getting very hot if it is connected for an extended period of time. The high resistance in the thin wire also results in lower current, so you may not get the compasses to respond as well as they do with the 18 gauge (thicker) wire. Along with the heat, leaving the wires connected to the battery will drain the battery very quickly.

Bring the class together to discuss their results. Ask a group to share what they found out in the investigation about the magnetic field around the coil.

Suggested prompts	Sample student responses	Follow-up questions
Would a group representative share what you figured out about the magnetic field around a coil of wire?	*We found out that there was a magnetic field and it had a direction.*	*What evidence do you have that tells you the field is present and that it has a direction?*
What patterns do you notice?	*The magnetic field seems to point out of one end of the coil and into the other.*	*Where have you seen this pattern before? (This pattern is the same as the pattern around a bar magnet.)*
Do you think a coil of wire that is connected to a battery or power source has a north pole and south pole like the bar magnet?	*yes*	*Can you label your sketches?*
What do you think causes the compass needle to move?	*forces* *energy*	*Are the forces transferring energy? How do you know?* *Where do you think the energy comes from?*

12. Revising Our Working Definition of Magnetic Field

10 MIN

Materials: science notebook

Recall the working definition for *magnetic field*. Say, *It seems we have learned some important things about a magnetic field since we first started our working definition. Find your working definition in your notebook and read what you wrote.*

After students have read their working definitions, ask, *What is missing from our definition?* Students should recognize that there is nothing about direction in the definition.

Revise the working definition of *magnetic field*. Display **slide W** and remind students that the definition on the slide is similar to the working definition that we came up with at the end of class on the first day of this lesson. Students should not copy this definition into their notebooks—it is just an example.

Have students add to their working definition of *magnetic field*. Students should see that they need to include something about direction in their definitions. Keeping what they already wrote, additions should be similar to this: **The magnetic field tells us what direction the force will be if we put another magnet in the field. The direction of the force is outward from the north pole and inward toward the south pole.** After students have had time to write additions to their definitions, ask 2-3 students to share their additions. If any students missed something that they hear from a peer during the sharing, have them add what they missed to their own definition at this time.

Additional Guidance

If students are struggling to come up with "direction", call attention to the ideas they have recorded in their notebooks that are related to the direction of the forces in the field. Students may have forgotten that the needles of a compass are actually small, permanent magnets and respond to one end of the magnet with attractive forces and the other end of the magnet with repulsive forces.

Some students may wonder about the direction of the force when they put iron filings in the field. We see iron filings line up in a magnetic field just like compass needles do. We know a compass needle is a tiny, permanent magnet, but what about iron filings? They seem to line up in the field the same way no matter how the magnet is turned. This is because the iron filings are ferromagnetic. They will become temporary magnets with temporary N and S poles when exposed to a magnetic field, but this magnetism might disappear in the absence of a magnetic field. A permanent magnet, on the other hand will retain the same north and south poles regardless of exposure to a magnetic field, unless that magnetic field is very, very strong. If the field is strong enough, it can demagnetize even a permanent magnet. A permanent magnet can also be demagnetized by exposure to heat, alternating current, or a collision.

Alternate Activity

For students who are curious about different kinds of magnetism and/or would benefit from an additional challenge, considering sending them to the library, the internet, or a community member with knowledge about magnets to research other kinds of magnets. These students could work together to research various types of magnetic materials (ferromagnets, paramagnets, permanent magnets, electromagnets, and so forth) and put together a "magnetic zoo" poster to put on the wall of the classroom.

13. Navigation

2 MIN

Materials: None

Motivate the next part of the lesson. Display **slide X** and ask students, *What would we need in order to see the magnetic field everywhere around a magnet in more detail, especially how the field changes as we move farther away from the magnet?* Tell students to turn and talk with an elbow partner about their ideas to gather more evidence and details about the magnetic field everywhere around a magnet or a coil.

End of day 3

14. Navigation

4 MIN

Materials: science notebook, computer

Share ideas for gathering more evidence. Display **slide Y**. Ask students to share some of their ideas about how to gather more evidence and details about the magnetic field everywhere around a magnet or a coil of wire. Accept all student ideas. They will likely say that they need a bunch of compasses. Some may suggest more-sophisticated compasses to measure more precisely or accurately. Tell students that these are great ideas, but you have a limited number of less-sophisticated compasses.

Connect the use of computer simulation to a common limitation (and solution) in science and engineering. Explain that when supplies are limited, which often happens as scientists and engineers dream up bigger investigations and identify the need or the benefit of collecting more and more data. At that point the person thinking up the investigation might decide to switch to using a computer simulation that enacts similar behavior to the system in the real world they want to study, since developing a computer simulation might be less expensive than conducting the investigation in the real world. For example, in a computer simulation it is easy to add more and more virtual objects, like many simulated compasses, at no extra cost once you develop the code for the basic rules of how a compass works and program it into the simulation. One example of such a rule to program into a computer simulation would be that the north end of a compass should point away from the north end of another magnet and toward the south end of that other magnet.

Prepare for students to use an interactive. Depending on the number of computers or tablets you have available, put students in groups with the smallest number of students possible. It is ideal if students each have their own device. Ensure that students can all access interactive. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

15. Use a computer interactive to model the field.

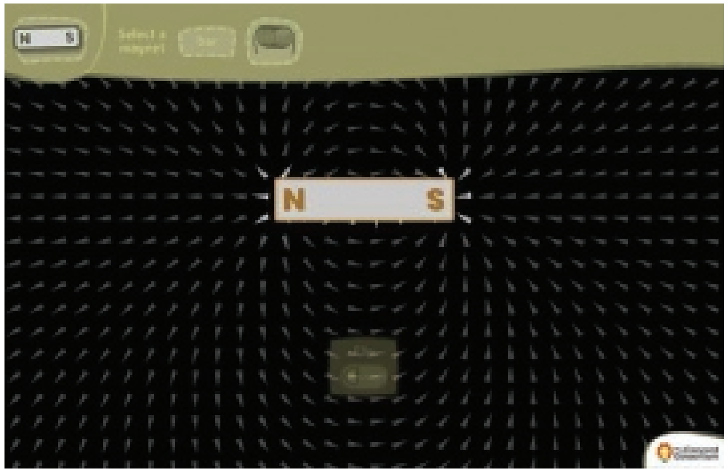
20 MIN

Materials: Investigating the Details of a Magnetic Field, science notebook

Connect the interactive to our investigation experiences. Remind students that scientists use computers to reproduce the behavior of a system so that they can see the effects on the system if there is a change to any part of it. We will use this interactive to reproduce the behavior of a system with a magnet and a coil, like in the speaker. We can use the interactive to explore how the magnetic field responds to changes in other parts of the system.

Have students access the interactive. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Ask, *What do you notice about the interactive that is similar to your investigations?* Students will likely say that they see little arrows or arrow heads that look like a bunch of compasses. Tell students that the arrows will point in the same direction as the compasses pointed around a magnet and a coil.

Make sure students understand how to choose a magnet and also how to choose a coil and battery. Tell them to "play around" with the interactive to learn more about the magnetic field and its shape around magnets and coils. They should also watch for how it changes depending on how far something is from the magnet. If any of these ideas are represented in the questions students have placed on the DQB, call attention to those now.



16. Add to the Progress Tracker. **10 MIN**

Materials: science notebook

Add to our Progress Trackers. Say, *You have recorded sketches from all of your investigations in this lesson. We found evidence to help us understand the magnetic field around both a magnet and a coil. Review all of what you have in your notebook under this lesson question. Then let's add any new ideas from using the interactive to Progress Trackers.*

Students should take a minute to review their annotated sketches of a field around a magnet and a field around a coil of wire and battery. Display **slide Z**. Allow time for students to add what they have figured out from the investigations and the interactive by using words, sketches, or both. They may add ideas as bullet points in their Trackers. Remind students that they should include everything they figured out that will help answer the lesson question, What can we figure out about the invisible space around a magnet?

17. Navigation and Exit Ticket **10 MIN**

Materials: scrap paper for exit ticket, *Reading: Finding the Way* (optional)

Reveal a gap in our understanding. Display **slide AA**. Say, *From this lesson we know what a magnetic field looks like around one magnet. But this system doesn't look like our speaker system.*

Ask, *How is the speaker different from the diagram on the slide?* Have students turn and talk with a partner. Listen for students to suggest that the speakers have both a permanent magnet and an electromagnet.

Say, *Our speakers have a permanent magnet and an electromagnet, both of which have magnetic fields. So we aren't getting the full picture.* Display **slide BB**. Say, *It seems that even though we have developed a better understanding of what happens to a compass with one magnet, we still haven't investigated a system with two magnets in it, like in our speaker.*

Let's use what we figured out about the field around one magnet to make some predictions about the field around a system with two magnets in it. For example, what would happen to a compass that I put right here? Point to the white, circled question mark on the slide. Look for students to suggest that the needle would align with the field.

Display **slide CC** and ask, *How would a compass respond here?* Point to a different white, circled question mark on the slide. Look for students to suggest that the needle would align with the field.

Ask, *But what would happen to a compass in the middle of a two-magnet system? How does it know which pole to follow at this point in space?* Display **slide DD** and ask students, *What happens when you have two magnets that are close? How would the magnetic field respond? Why?* Have students respond to this prompt as an exit ticket. Tell students that they can use words or diagrams to illustrate the effect they predict on the magnetic field. Remind them not to forget a justification for their prediction.

Assessment Opportunity

In this exit ticket, students will apply what they know about forces in a magnetic field that cause compass needles to respond in a predictable way to predict the effect of the magnetic fields on a compass needle placed in between two magnets. Do not expect student representations to be accurate. Review these exit tickets for the modeling conventions that the class has been using in this lesson for the patterns we see in magnetic fields, including (1) using pointers to indicate the field; (2) illustrating the space around the entire magnet (or magnets), not just on one side; and (3) pointers coming out of the north pole and into the south pole. If necessary, remind students of these conventions before launching into the activity of the next lesson.

Home Learning Opportunity

Optional reading: There is an optional reading associated with this lesson that will help students make connections between their prior experiences with compasses and the compasses that they are using as test objects. If you would like to include this reading as a home learning activity, there is an option to process the information from the reading at the start of Lesson 5. Display **slide EE** and distribute a copy of *Reading: Finding the Way* to each student. There is a copy of this reading, *Finding the Way*, in the Student Edition for reference as well. Explain that close reading requires reading more than once and with different purposes and strategies each time for interacting with the text. Point to the close reading strategies included in the handout. Tell students that we will process the reading together briefly in Lesson 5.

SCIENCE LITERACY: READING COLLECTION 2

Beyond Magnets

1 **Ben Franklin's Kite**
2 **Engineering Blog**
3 **Pushing and Pulling Without Touching**
4 **Earth Is a Magnet**
5 **No Touching**

Literacy Objectives

✓ Use reading to explain how forces can act on objects without touching them.
✓ Use reading to describe and compare noncontact forces of gravity, magnetism, and static electricity.
✓ Use descriptions of noncontact forces to identify uses of those forces.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 3–4.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a description of waking up in zero gravity in response to the reading.

Instructional Resources

Student Reader Collection 2	**Science Literacy Student Reader, Collection 2** "Beyond Magnets"
Exercise Page EP 2	**Science Literacy Exercise Page** EP 2

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 3: How does energy transfer between things that are not touching?
- Lesson 4: What can we figure out about the invisible space around a magnet?

Standards and Dimensions

NGSS Performance Expectation MS-PS2-3: (Building toward) Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

Disciplinary Core Ideas PS2.B: Types of Interactions; **PS3.A:** Definitions of Energy

Science and Engineering Practices: Asking Questions; Constructing an Explanation

Crosscutting Concepts: Cause and Effect; Systems and System Models

CCSS

English Language Arts

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

W.8.3: Write narratives to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sequences.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

electrostatic force

gravity

magnetic field

magnetism

noncontact force

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

engineering

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

Exercise Page

EP 2

2. Preview the assignment and set expectations.

MONDAY

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Forces at a Distance unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *In "Ben Franklin's Kite," you will learn about the force of static electricity, and find out how static electricity can act on objects without touching them.*
    - *In "Engineering Blog," you will read about electrostatic force used in engineering designs to remove pollutant particles from air.*
    - *"Pushing and Pulling Without Touching" will help you compare three noncontact forces—magnets, gravity, and static electricity—and see how they come in handy in everyday life.*

- *In "Earth Is a Magnet," you'll learn why Earth is a giant magnet.*
- *The final selection displays various pieces of artwork that are created by noncontact forces.*

- Distribute Exercise Page 2. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a visual or text-based description of what it would be like to wake up in a familiar room without gravity.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

WEDNESDAY

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What are three different forces that act on objects without touching them?	*static electricity, magnetism, and gravity*
What are three ways you rely on gravity?	*When I throw something in the air, it falls back to Earth.*
	I can walk with my feet on the ground, and I do not float off Earth.
	Tables and chairs stay on the ground without being bolted down.
How might living in zero gravity compare to swimming in water?	*Unlike zero gravity, swimming in water is controlled by gravity, but you can experience a lighter weight and objects acting differently.*
	Unlike floating in zero gravity, your movements are affected by water when you are floating.

Suggested prompt	Sample student responses
How have you experienced static electricity?	*socks clinging to the dryer tub*
	getting a shock when you touch a metal object when walking across a rug
	hair clinging to your face or hat
	rubbing a balloon on your sweater and sticking it to a wall

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How do you know static electricity, gravity, and magnetism do not need air to work?	*They still work even on a windy day or if air is blocked.*
What is a magnetic field?	*A magnetic field is the space around a magnet that seems to push and pull certain things. The magnetic field is stronger closer to the magnet.*
How big is a magnetic field?	*It can be small with a small magnet, or it can be large with a large magnet.*

- Refer students to the Exercise Page 2. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to create a description of what it would be like to not have gravity.*
    - *In the selections, you read about how gravity works on objects without touching them.*
    - *Think about what you read and know about living in space. Think about the things that you appreciate will stay in place because of gravity.*
    - *Write or draw a description of waking up to find there is no gravity in your room.*
    - *Make your description engaging, maybe even funny, to make your readers think about the effects of this wacky scenario that they would not necessarily think about. A great description will be about everyday objects that do not act as expected.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 2

4. Facilitate discussion.

FRIDAY

Facilitate class discussion about the reading collection and writing exercise.

The five reading selections help to explain how different noncontact forces—gravity, magnetism, and static electricity—affect the way we live. We rely on noncontact forces every day without always realizing it.

Student Reader

Collection 2

Pages 12–13 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Ben Franklin's Kite"?	*It explains what static electricity is.* *It describes how static electricity works on objects without touching them.*
How is movement related to static electricity?	*Static electricity occurs with the movement of an electric charge caused by contact or friction between two objects.*
What is static electricity?	*It is a type of electricity that occurs when the positive and negative charges are not balanced on surfaces.*
Why is static electricity worse in dry weather, and why does it occur in the dryer and not the washer?	*Static electricity is everywhere all the time. We don't notice it because moisture prevents charges from building up. In dry conditions, the static electricity builds up and is stronger. Therefore, we see socks clinging to the inside of a dryer.*

Pages 14–15 **Suggested prompts**	**Sample student responses**
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first selection was about static electricity as a noncontact force. This selection describes a useful application of electrostatic force.*
How is a noncontact force used in the technology described in this selection?	*Differing charges between materials in air-cleaning devices and particles in the air pull the particles out of the air. This leaves the air cleaner.*

Page 16 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third article, "Pushing and Pulling Without Touching"?	*It describes how gravity, static electricity, and magnetism affect objects without touching them.*
How do noncontact forces make life on Earth possible?	*Gravity holds everything to the surface of Earth.* *Without gravity, everything would be floating around.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Some students may benefit from taking more time to differentiate between magnets, gravity, and static electricity, in order to fully grasp the difference between these noncontact forces and how each of them work.

Some students may benefit from differentiating between gravity and zero gravity. Have students demonstrate gravity by dropping a small object. Then discuss what would happen to the object in a non-gravity (zero gravity) scenario.

CHALLENGE—Have interested students research uses of controlled static electricity, for example, in pollution control, painting cars, and air fresheners.

EXTEND—If students have enough time, have them watch a 30-minute video that shows how astronauts live in zero gravity.

Page 16 **Suggested prompts**	**Sample student responses**
	Magnetism powers all kinds of things that people rely on each day, including computers, appliances, and simple closures for handbags.
Can you turn noncontact forces on and off?	*You can turn controlled forms of static electricity and electromagnets on and off.*
	Natural forces of static electricity, magnetism, and gravity are always acting on objects. These cannot be turned off.
Is gravity a strong or weak force on Earth?	*It seems like it is strong because it holds everything in place, but it is also weak in that you can overcome it, for example, by throwing a ball into the air or jumping up and down.*
What would life on Earth be like if gravity were a much stronger force?	*Most things would be flattened against the ground.*
	Everything would weigh much more.
	It would be much more difficult to move or jump.
	We would not be able to throw things into the air.

Page 17 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth article, "Earth Is a Magnet"?	*This selection explains that because Earth's core is made of magnetic nickel and iron, it is a giant magnet and has its own magnetic field.*
Is it gravity or magnetism that keeps Earth in orbit?	*gravity*
	All bodies in the universe attract each other with a force that is relative to how big they are and how far apart they are.
What evidence is there that Earth is a magnet?	*Magnetic compasses move in relationship to the poles.*
	Earth's magnetic field repels a lot of objects from space.

Pages 18–19 **Suggested prompt**	**Sample student responses**
How does the last selection relate to the other selections in this collection?	*It describes art applications of using noncontact forces.*

Pages 18–19 Suggested prompts	Sample student responses
Why are pieces of art made by natural noncontact forces in predictable patterns?	*because they copy the patterns of the natural forces themselves and those natural forces move in predictable patterns*
How could you use magnetism to make artwork with iron shavings?	*Many toys allow you to arrange magnetic shavings using a magnet that attracts and arranges the shavings.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 2, students should create a text-based or visual description of what it would be like to live in zero gravity. They could write a story or draw what zero gravity would be like and should be encouraged to be creative and apply a sense of humor!

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 5

How does the magnetic field change when we add another magnet to the system?

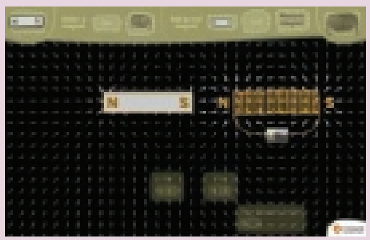
Previous Lesson

We learned that the space around a magnet is called a magnetic field and that this field appears to affect the behavior of certain objects. We tested the field around a bar magnet and an electromagnet using iron filings and compasses. We took compasses home to document the places in our lives where we found magnetic fields. We wondered—what happens to the magnetic field when we add a second magnet?

This Lesson

Investigation

1 DAY



We use a computer interactive to map the magnetic field around a magnet and a coil of wire in four different configurations: (1) when the coil and the magnet are close and oriented so that the forces between them are attractive, (2) when the coil and the magnet are farther apart and oriented so that the forces between them are attractive, (3) when the coil and the magnet are close and oriented so that the forces between them are repulsive, and (4) when the coil and the magnet are farther apart and oriented so that the forces between them are repulsive. This leads us to wonder—How do the changes we see in the simulated magnetic field due to changes in distance change the behavior of the magnets in real life?

Next Lesson

We are ready to start putting the pieces together to explain the interactions we have noticed between the magnet and the coil of wire using magnetic fields. We will record the cause-and-effect relationships that we figured out in Lessons 2-5. Then we will construct a class consensus model to explain these relationships and how they work together to produce the movement we see between the magnet and the electromagnet.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Use a computer interactive to model the effect on the patterns in the magnetic field when we add an electromagnet to the single magnet system.

What Students Will Figure Out

- When we look at the magnetic field around two magnets (or a magnet and a coil of wire), the magnetic field looks different than if we are looking at only one magnet.
- When the forces are attractive (i.e., S-N or N-S), then the magnetic field connects in the middle with a line of compass needles pointing in the same direction.

- When the forces are repulsive (i.e., S-S or N-N), then the compass needles curve away from each other in the middle.
- It is hard to tell what happens when we move the magnet and the coil closer together.

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION**	A	
2	15 min	**COMPUTER INTERACTIVE** Students use the simulation to explore the magnetic field between a magnet and a coil.	B-E	class key poster (created in Lesson 2), Modeling the magnetic fields between a coil and a magnet
3	20 min	**COMING TO CONSENSUS ABOUT THE FIELDS BETWEEN THE MAGNET AND THE COIL** Students develop a consensus model for the fields between the magnet and the coil.	F-G	
4	5 min	**NAVIGATION** Ask students to reflect in an exit ticket on the difference between attractive and repulsive forces. This will set students up for putting the pieces together in the next lesson.	H-I	

End of day 1

Lesson 5 • Materials List

	per student	per group	per class
Modeling the magnetic fields between a coil and a magnet materials	• science notebook	• computer with access to Magnets (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)	
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook		• class key poster (created in Lesson 2)

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the Lesson 5 version of the computer interactive on the computers that students will be using. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 4 students learned that magnetic fields explain the interactions they observe when they bring small, magnetic objects near a magnet. They used a computer interactive to model and diagram this field. But in order to explain the speaker, they need to be able to diagram a more-complex set of magnetic fields. In this lesson, students use a computer interactive to model the magnetic field between a magnet and a coil of wire. They do this for both attractive and repulsive forces and for when the magnets are both close together and far apart. Students need these representations in order to model the changes to the magnetic field in the speaker that explain the pushes and pulls needed to make different kinds of sounds.

Where We Are NOT Going

Students will not necessarily be using magnetic field lines in their diagrams. The computer interactive uses arrows representing compass needles to indicate direction of forces in the field. If it is important for your class to use magnetic field lines, consider printing a screenshot from the interactive and asking students to "connect the dots" in order to make the connection between the more-abstract field line representation and the concrete representation of the compass needles.

1. Navigation

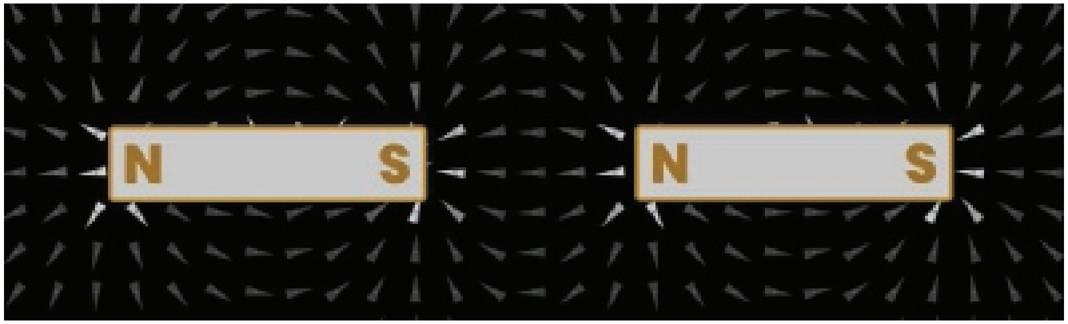
5 MIN

Materials: science notebook

Review the gap in our understanding. Display **slide A**. Say, *In the previous lesson, we figured out that there is a magnetic field around a magnet that describes the forces on another object, like a compass, when we put it nearby. So if we put a compass near a magnet, the forces will align the compass so that its arrow lines up with the arrows of the magnetic field. But if we have two magnets or a magnet and a coil, what would happen to a compass in the middle? How does it know which arrow to follow?*

Ask students to turn and talk with a partner and then record a cause-effect prediction in their notebook under the lesson question: How does the magnetic field change when we add another magnet to the system? Remind them to use the structure: "When we add a second magnet to the system, then we will observe …."

Elicit 1-2 student predictions if students want to share, otherwise move on by suggesting, *I have another version of the computer interactive we used in Lesson 4. In this version we can add another permanent magnet or a coil connected to a battery. Let's use this to test out our predictions.*



2. Computer Interactive

15 MIN

Materials: Modeling the magnetic fields between a coil and a magnet, class key poster (created in Lesson 2)

Set up science notebooks to record the fields. Display **slide B**. Use the instructions on the slide to guide students in setting up their notebooks. Tell students to turn to a new 2-page spread in their notebooks. Across the top, they should label the pages "Magnetic Fields Between a Magnet and a Coil of Wire." Below, students should label the left page "Attractive forces" and the right page "Repulsive forces." They should then draw a horizontal line across the middle of the pages and label the rows "Big gap" and "Small gap."

Motivate investigating the size of the gap between the magnet and the coil. After students have set up their notebooks, display **slide C**. Ask students to turn and talk about the question on the slide, *Why do we care about the size of the gap between the coil and the magnet?* Ask 1-2 students to share out.

*** Attending to Equity**

Many students need additional support for the development of new vocabulary, including students who are emergent multilinguals, students who have been diagnosed with learning differences, and students who need more time to process new words. If you think that your students would benefit from revisiting the definition of *magnetic field*, do so at the beginning of this lesson. Ask, *What is a magnetic field?* Instruct students to turn to the definition that they developed in their notebooks from the previous lesson and then to come up with a different way to describe in their own words what a magnetic field is. They should turn and talk with a partner before sharing with the class. Ask several students to share their ideas about what a magnetic field is. Look for students to suggest that magnetic fields describe what would happen to a compass if we put it near a magnet. Probe students to clarify their definitions. For example, you can ask questions such as these:

- If I move a compass from one arrow to another in a magnetic field, what might I see happen?

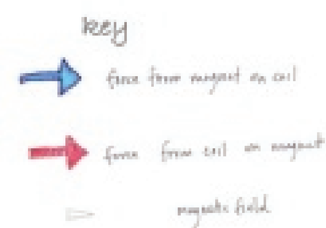
Suggested prompt	Sample student responses
Why do we care about the distance between the coil and the magnet?	*because in the speaker, they get closer together and farther apart* *because in the speaker, the magnet and the coil were super close together and we don't know why* *because when we brought the magnet closer to the cup in the homemade speaker it got louder, and we had questions about that*

- What do the little arrows in the magnetic field representation tell us?
- How are these lines related to the forces the compass will experience?

Additional Guidance

Consider asking students to find the questions on the DQB related to the distance between the magnet and the coil and read them aloud to the class to remind us of why we might include two versions of the diagram for each type of force (close together and farther apart).

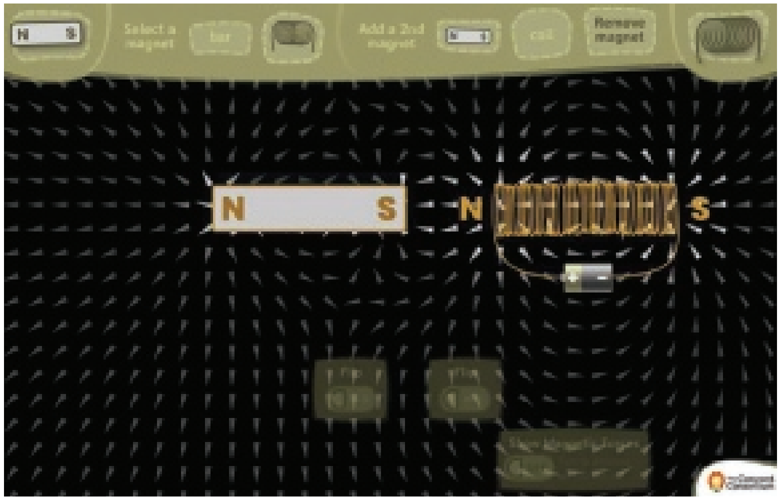
Create a convention for representing the magnetic fields and add it to the class key. Say, *Before we get started in our investigations, let's come up with a convention for representing direction of forces in a magnetic field that we can all use to quickly record our results from the simulation. This will help us more easily share and compare findings among groups. Let's use pencil to draw magnetic fields. That way we can erase something if we make a mistake or change our mind, and it is lighter than the rest of the diagram so we remember it is invisible.*



Add this convention to the class key poster that we began in Lesson 2, which should be hanging where students can see it. Ask students to copy this key into their notebooks someplace on the 2-page spread, leaving room for their magnetic field diagrams.

Introduce students to this version of the computer interactive. Break students into pairs and make sure each pair has a computer with access to the interactive. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Make larger groups if the number of devices is limited. Display **slide D**. Note the changes to the interactive:

- Students now have the option to include both a coil and a magnet in the investigation sandbox at the same time.
- Students can drag both the coil and the magnet around the investigation sandbox and flip the orientation of either or both objects.



Remind students that scientists use computers to reproduce the behavior of a system so that they can see the effects on the system if there is a change to any part of the system. We will use this interactive to reproduce the behavior of a system with a magnet and a coil, like the speaker. We can use the interactive to see how the magnetic field responds to changes in other parts of the system.

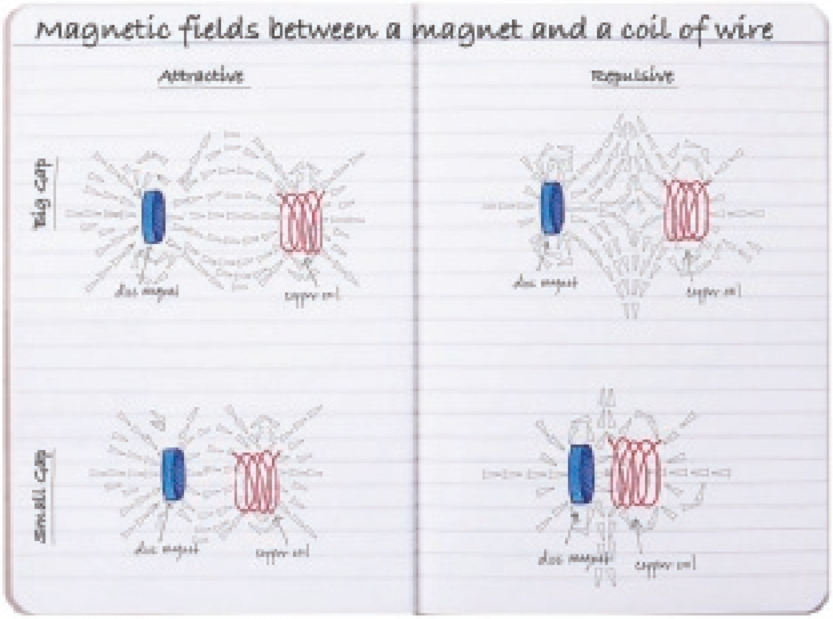
Display **slide E**. Say, *First, use the interactive to find out what is happening in a big gap between the magnet and the coil when you simulate forces that are attractive. Record the fields that you observe in your notebook at the top of the left page. You can drag the magnet and coil around to change the size of the gap. Then simulate forces that are attractive for when there is a small gap.*

Leave it up to student teams to figure out how to change the magnetic forces from attractive to repulsive. As you circulate the room, scaffold groups who are struggling by suggesting that they look back in their notebooks to Lesson 2 where we investigated the magnet and the coil. Ask, *What did we do in the Lesson 2 lab with the coil and the battery in order to get the magnetic forces to switch direction?* Look for students to remember that they flipped the magnet (or the coil) around in order to get the forces to switch direction.

3. Coming to Consensus About the Fields Between the Magnet and the Coil 20 MIN

Materials: None

Share student models. Display **slide F**. Ask 3-4 students to share their diagrams with the class. Ask other students to indicate areas of agreement and disagreement on their own diagrams as they listen to their peers. Then create a class version of the diagrams on chart paper. Consider using a gray marker instead of pencil to represent the magnetic field on the class version so that everyone can see.



Additional Guidance

To save time, this discussion is done as a class, but not in a Scientists Circle. If the logistics of convening in a Scientists Circle are not too time consuming for you, consider using that participation structure to have this discussion.

Display **slide G**. Ask students to turn and talk with a partner about how to describe the differences between the two magnetic fields. Then ask 1-2 students to share out.

Look for students to make these suggestions:

- When we look at the magnetic field around two magnets (or a magnet and a coil of wire), the magnetic field looks different than if we are looking at only one magnet.
- When the forces are attractive (i.e., S-N or N-S), then the magnetic field connects in the middle with a line of compass needles pointing in the same direction.
- When the forces are repulsive (i.e., S-S or N-N), then the compass needles curve away from each other in the middle.
- It was hard to tell what happens when we move the magnet and the coil closer together.

Key Ideas

Purpose of the discussion: To establish consensus around how to represent the magnetic fields around a magnet and a coil, both when the forces are attractive and when they are repulsive.

Listen for these ideas:

- When we look at the magnetic field around two magnets (or a magnet and a coil of wire), the magnetic field looks different than if we are looking at only one magnet.
- When the forces are attractive (i.e., S-N or N-S), then the magnetic field connects in the middle with a line of pointers pointing in the same direction.
- When the forces are repulsive (i.e., S-S or N-N), then the pointers curve away from each other in the middle.
- Though the shape of the field changes on the sides of the magnets when we move them closer together or further apart, it was hard to tell what happens in the space directly between them when we move the magnet and the coil closer together or further apart.

4. Navigation

5 MIN

Materials: None

Motivate a conversation about what else is happening in the field. Display **slide H**. Ask, *What happened when we pushed the magnet and the coil closer together?* Accept all ideas but expect that students will struggle to articulate a difference, particularly related to what is different about the field in the space directly between the two magnets.

Say, *We have a lot of ideas. The interactive didn't really tell us about what happened in real life when we bring magnets together or, for that matter, when we pull the magnets apart. Do you think we would notice something else changing in the field if we brought two real magnets together? And since we can't actually see the field itself, what, if anything, do you think we will actually be able to observe happening in a real two-magnet system?*

Display **slide I**. Assign the questions on the slide as an exit ticket:

- Without a compass or an interactive to help us map the magnetic field, what, if any, effect do you predict we will be able to observe in the system when we bring two magnets closer together if the forces between them are <u>attractive</u>? Use a cause-effect sentence to write your prediction.
- Without a compass or an interactive to help us map the magnetic field, what, if any, effect do you predict we will be able to observe in the system when we bring two magnets closer together if the forces between them are <u>repulsive</u>? Use a cause-effect sentence to write your prediction.

Motivate putting the pieces together. Say, *We have accomplished so much. We figured out that invisible magnetic fields are responsible for the interactions we saw between the magnet and the electromagnet in the speaker. Next time, let's see if we can put together some of our ideas to explain how this happens and help us determine if there is anything else about how a speaker system works that we still need to figure out.*

LESSON 6

How can we use magnetic fields to explain interactions at a distance between the magnet and the coil?

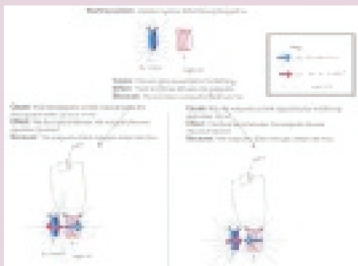
Previous Lesson

We were wondering what happens to a test object that is in the middle between two magnets, each with their own magnetic field. We used a computer interactive to map the magnetic field around a magnet and a coil of wire in four different configurations. This led us to wonder—How might the changes we saw in the simulated magnetic field due to changes in distance change the behavior of the magnets in real life?

This Lesson

Putting Pieces Together, Problematizing

3 DAYS



We are ready to start putting the pieces together to explain the interactions we have noticed between the magnet and the coil of wire using magnetic fields. We record the cause-and-effect relationships that we figured out in Lessons 2-5. Then we construct a class consensus model to explain these relationships and how they work together to produce the movement we see between the magnet and the electromagnet. We still have a lot of gaps in our model that we want to investigate, mostly around the electromagnet. How does it work? And how does it produce both pushes and pulls when it is connected to a music player instead of a battery?

Next Lesson

We will plan and carry out an investigation using a cart on a track to determine how changing the distance between two magnets affects the energy transferred out of the magnetic field. We will construct explanations based on evidence to support the claim that changing the distance between two magnets affects the amount of energy stored in and transferred out of the field between them for both attractive and repulsive forces.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Develop an initial model to describe how forces and energy transfer in magnetic fields explain cause and effect relationships between parts of a speaker system (magnet and coil of wire).

Ask questions about how interactions between parts of a speaker system (magnet and coil of wire) cause sound without those parts touching each other.

What Students Will Figure Out

- Forces in an invisible magnetic field produce the movement we observe between a magnet and an electromagnet without touching.

- Flipping either magnet so that like poles are facing will change the magnetic field shape so that there will be repulsive forces between them.
- Flipping either magnet so that opposite poles are facing will change the magnetic field shape so that there will be attractive forces between them.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review some of what we have figured out in the most recent lessons.	A-B	
2	20 min	**TRACING CAUSE-EFFECT RELATIONSHIPS** Students work in groups to come up with a list of cause-effect relationships that we have uncovered in the first lesson set. The class then records a consensus list of the relationships we think are most important for understanding how the speaker works.	C-D	*Lesson 6: Cause-Effect Table*, Cause-Effect Tracker poster (created in this lesson)
3	17 min	**MAKE MODELS IN GROUPS** Students convene in small groups to refine a model for explaining how the magnets in the speaker work without touching.	E	chart paper, colored pencils, markers
4	3 min	**NAVIGATION** Students complete an exit ticket in preparation for the class consensus model they will construct together in the next class.	F	piece of scrap paper
				End of day 1
5	13 min	**COMPARE MODELS IN A GALLERY WALK** Coordinate a gallery walk for students to identify ideas they saw used in other groups' models that might be useful for the class consensus model.	G	
6	32 min	**BUILD A CONSENSUS MODEL IN A SCIENTISTS CIRCLE** The class collaborates on a consensus model for the speaker.	H-J	chart paper, colored markers, colored pencils, sticky notes
				End of day 2
7	20 min	**ASSESSMENT** Students take a midpoint assessment transfer task.	K-L	*Figuring out the doorbell*, doorbell with cover removed

Part	Duration	Summary	Slide	Materials
8	10 min	**IDENTIFYING GAPS IN WHAT WE KNOW** Students identify gaps in what we know to motivate the investigations in lessons 7 and 8.	M	pen, sticky notes, Consensus Model poster
9	15 min	**NAVIGATION** Navigate to the next lesson.	N-Q	1 pad of arrow-shaped sticky notes, Class Consensus Model poster
				End of day 3
		SCIENCE LITERACY ROUTINE		Student Reader Collection 3: *Gravity and Earth*

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Lesson 6: Cause-Effect Table* • piece of scrap paper • *Figuring out the doorbell* • pen	• chart paper • colored pencils • markers • 1 pad of arrow-shaped sticky notes	• Cause-Effect Tracker poster (created in this lesson) • chart paper • colored markers • colored pencils • sticky notes • doorbell with cover removed • Consensus Model poster • Class Consensus Model poster

Materials preparation (45 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare chart paper for posters.

- For the Cause-Effect Tracker poster, write the title at the top of a piece of chart paper and then sketch a table with three columns. Label the columns "Change to the system (cause)," "Effect on the system," and "How or why." Add sticky notes to remind students of the sentence frames we have been using to describe cause-effect relationships. To the left of the table, put a note that reads "When we". On the line between the first and second columns, put a note that reads "we will observe". On the line between the last two columns of the table, place a note that reads "because."
- Title the Class Consensus Model poster.

Find space for students to put up their group posters for the gallery walk.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

In third grade, students may have learned that electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact. They may also have learned that the sizes of the forces in each situation depend on the properties of the objects and their distance apart and, for forces between two magnets, on their orientation relative to each other (3-PS2.B). This lesson brings together key ideas that magnetic forces between two interacting magnets can be attractive or repulsive and that the direction of these forces depends on the orientation of the magnet (L2). In the next lesson set, students will add the idea that the direction of current flow in an electromagnet is also a factor determining the direction of the forces in a magnetic field. This lesson adds new ideas developed about magnetic fields during Lessons 3-5, specifically that a magnetic field is a region of space around a magnet (or multiple magnets) that appears to affect the behavior of certain objects (i.e., test objects). The field determines the direction of the magnetic force on a test object placed in the field.

Where We Are NOT Going

While students will explain many aspects of how the doorbell system works as part of the midpoint assessment, there is one aspect of its behavior that will not be addressed in this lesson. The following information is for the teacher only and is not a focus of the assessment nor this lesson:

- The hammer of the doorbell strikes the bell when a battery is initially hooked up to the system because the coils become electromagnets as current flows through them. This attracts the iron hammer which pulls the hammer arm toward the coils and causes the end of it to strike the bell.
- But as the end of the hammer moves toward the coils and strikes the bell, there is a small part of the path that the electric current from the battery is flowing through that is broken—a small air gap is formed in it. You can see where this happens at a location where sparks appear between the hammer and the copper contact points when the bell is ringing.
- This is a designed feature of the system, because once this gap forms the coils stop being electromagnets. The attractive force between the coils and hammer ceases, and the hammer arm then springs backward from its deformed shape (due to its elastic nature).
- Once it returns to its initial position, the hammer arm reestablishes contact with the circuit that the current can now flow through. When this happens the coils become electromagnets again and pull the hammer toward them, causing the end of the hammer to strike the bell again. And the cycle repeats.
- In this way the coils switch from being connected to the battery to being disconnected from it very quickly, causing the hammer to strike the bell many times a second, producing its characteristic continuous ringing sound.

This is an example of a physical system that delivers rapid pulses of electricity and no electricity through the coils, which causes a structure in it (the arm) to move back and forth. In that way, it is somewhat similar to how a speaker works. But don't focus on this vibration of the arm in this lesson, nor the changing pattern of electric current that might be changing in the system. It is too early to introduce these ideas and therefore too early to show students this aspect of the doorbell's behavior. Students will propose one candidate explanation for how a speaker works in the next lesson that includes the idea of rapid pulses of electricity being provided to the coil from the electronic music player. But they will first need to get a clear line of evidence for that candidate explanation, which they will do through a hands-on investigation in the next lesson.

1. Navigation

5 MIN

Materials: science notebook

Take stock of what we know about the speaker. Project **slide A** that shows a photo of dissected speaker parts and have students open their science notebooks to the page where they have their original models for the speaker system from Lesson 1. Discuss the focus of our investigations over the course of Lessons 1–5.

Suggested prompts	Sample student responses
When we decided to investigate the magnet and the coil in this set of lessons, what were we trying to explain?	*how the magnet could be pushing or pulling on the coil without touching*
What were some of the surprising things we've figured out when we started to investigate the speaker and its different parts?	*We found out that the wire is a magnet when it's carrying a current.*
What were some of the surprising things we've figured out when we started investigating the space around the magnet and the coil or wire?	*We found out it is not related to air. The field around the magnet is something different from matter.* *The field can tell us the direction of the forces if you put something in the field.*

Say, *When we started investigating the space around our magnets, we wanted to know how the magnets in the speaker work when they do not touch. We've done some mapping of this space and have learned that it's called a magnetic field and the field determines the direction of the forces between the two objects. Today let's see if we can put the pieces together and try to use what we figured out about magnetic fields to explain how the magnet and the coil of wire exert forces on each other without touching.*

Introduce the lesson question. Present **slide B** and introduce students to the question, "How can we use magnetic fields to explain interactions at a distance between the magnet and the coil?"

2. Tracing Cause-Effect Relationships

20 MIN

Materials: science notebook, *Lesson 6: Cause-Effect Table*, Cause-Effect Tracker poster (created in this lesson)

Use a cause-effect table to document what we know. Display **slide C**. Pass out *Lesson 6: Cause-Effect Table*. Say, *We noticed in Lesson 1 that when we plug the speaker into the music player and turn on the music player, the speaker produces sound. Let's make a list of some cause-effect relationships that we have uncovered since then. Take some time to look back in your notebook for ideas. Look for specific changes that we made to the system so far and the effects that we observed when we made those changes.* Hand out *Lesson 6: Cause-Effect Table*. Instruct students to work in small groups to begin filling out the table in the handout.

As students work, make sure that the Cause-Effect Tracker poster that you have prepared ahead of time is hung near the front of the room. After 8 minutes, solicit student ideas about changes that we made to the system. If students are stumped, consider scaffolding their brainstorming by going lesson by lesson, as in the prompts below.

Suggested prompts	Sample student responses	Follow-up questions
What changes did we make to the system in Lesson 2?	*We connected the coil of wire to a battery.*	*What was the effect of the battery on the system and how or why did that change cause that effect? (Record this in the poster table.)*
	We flipped the orientation of the magnet and the coil.	*What were the different orientations we were flipping between? (Look for students to suggest N-N and S-S vs. N-S.)* *What was the effect on the system for each orientation, and how or why did those changes cause those effects? (Record this as two separate cause-effect relationships.)*
What change did we make to the system in Lesson 3?	*took the air out of the system*	*Did that have an effect on the system? If not, it is not a cause-effect relationship. (Do not record anything from Lesson 3 in the class table.)*
What change did we make to the system in Lesson 4?	*added test objects to the system*	*What was the effect on the system, and how or why did that change cause that effect?* *Did we learn anything in this lesson that can help us flesh out our cause-effect relationships from Lesson 2? (Look for students to use the magnetic field as a causal mechanism.)*
What change did we make to the system in Lesson 5?	*added a second magnet to the interactive*	*What was the effect on the system, and how or why did that change cause that effect?* *Did we learn anything in this lesson that can help us flesh out our cause-effect relationships from Lesson 2? (Look for students to use the changes in the magnetic field as a causal mechanism.)*

Make a public record of our ideas. As students share their ideas, ask, *Did anyone else record a similar relationship?* If another group (or groups) volunteers "yes", ask them to share with the class what they wrote. Then either rephrase the relationship to capture the most important pieces from each version or ask, *Can someone summarize what these groups are saying?* Record student ideas in the Cause-Effect Tracker poster. As students share, ask, *In which lesson did you make that observation?* Record the lesson number in the table, next to the idea that we figured out in that lesson, as shown below. Note that sometimes we figured out a cause-effect relationship in one lesson, but did not figure out the how/why until a later lesson. If students are not sure about a how or why relationship, ask the class to brainstorm ideas.

Highlight how or why relationships that we still have questions about. If students suggest taking the air out of the system, use probing questions to clarify their thinking, revealing that there was no effect and this relationship is not important to understanding the speaker. Consider not including it in the table or including it but crossing it off to indicate that this will not be part of our model. You should end up with a table similar to the one below.

	Change to the system (cause)		Effect on the system		How/Why
When we	L2: plug the coil into the battery	**we observe**	there are forces between the coil and the magnet (or the coil moves, or it becomes an electromagnet)	**because**	there is a magnetic field around both of them and in between them. (L4)
When we	L2: flip the magnets so that opposite poles are facing each other (S-N)	**we observe**	the force pairs between the magnets become attractive (pulls)	**because**	the shape of the magnetic field between them changes. (L5)
When we	L2: flip the magnets so that similar poles are facing each other (S-S or N-N)	**we observe**	the force pairs between the magnets become repulsive (pushes)	**because**	the shape of the magnetic field between them changes. (L5)
When we	L4: add test objects to the system	**we observe**	the test objects line up in predictable patterns	**because**	there is a magnetic field around a magnet that changes direction as you move around or away from the magnet. (L4)
When we	L5: add a second magnet to the interactive	**we observe**	the magnetic field changes	**because**	there are now two magnetic fields affecting a test object, so the force on the object is different. (L5)

Emphasize that words are not enough. As you go, use probing questions to highlight the hows or whys about the magnetic field that are difficult to explain in words. For example, if students suggest that the "magnetic field changes," record this idea in the table and then ask, *Can you describe how the magnetic field changes?* Students will most likely stumble over this explanation as it is hard to articulate. Say, *It sounds like we have some ideas about what this change looks like, but it's really hard to explain those ideas in words. Let's keep this wording for now, and then we'll use a visual model to explain it better later.*

Once the table is complete, display **slide D**. Ask students to turn and talk about the question on the slide: Which of these cause-and-effect relationships do we need to explain the interactions between a coil and a magnet that are not touching? After a couple of moments, ask students to nominate some important cause-effect relationships and explain why they think they will be important. Highlight or underline the relationships students nominate. Look for students to suggest almost every relationship except those that refer to test objects that come out of Lessons 4 and 5. If students suggest the Lesson 4 or Lesson 5 relationships, ask, *What is important here, the cause and effect of what happens to the test objects or the nature of the magnetic field that the test object helped us visualize?*

Say, *It's hard to articulate a lot of these hows and whys without actually drawing the system. So today we are going to build a model in small groups of what we have figured out so far, and maybe that will help us represent those hows and whys more clearly while also giving us an opportunity to uncover some aspect of the system that we still don't know about so that we have an idea of where to go next.*

3. Make models in groups. 17 MIN

Materials: science notebook, chart paper, colored pencils, markers

Think independently in student notebooks. Remind students that the purpose of building individual models is to gather their initial thinking. They will have a chance to share ideas in small groups, and then the whole class will discuss how to put these pieces together.

Remind students of the resources we have for constructing a diagrammatic model:

- the magnetic fields we drew in our notebooks in Lessons 4 and 5
- the list of cause-effect relationships that are important for understanding the speaker that we just made as a class

Tell students, *We want to capture what we figured out about cause and effect in our models, so we may need to draw the system several times in order to capture all the important relationships*. Give students at least five minutes to record some of their initial ideas in their notebooks.

Remind students of discussion norms. Remind students of the Communicating in Scientific Ways chart and emphasize your class's discussion norms to help support productive scientific discussions as the students work with their groups. Emphasize the importance of having a safe space where students can share their ideas and push one another's thinking.

Revise a model in groups of 3-4. Form small groups with no more than four students each. Give groups 12-15 minutes to work on a set of collaborative models for explaining how the magnets in the speaker make things move without touching (use **slide E** to orient students to the task). Have students draw their models on a large piece of chart paper. The students should keep the list of cause-effect relationships that they copied into their notebooks nearby to check off ideas as they are included in the model.

Ask students to post their models in the classroom, in the hallway just outside the classroom, or in a place you designate so that other groups can view their models.

4. Navigation 3 MIN

Materials: piece of scrap paper

Ask students to evaluate their group's model on an exit ticket. Present **slide F**. On a piece of scrap paper, ask students to respond to the following prompt:

- What do you think is still missing from your model that is needed in order to explain how a speaker works?*

Collect students' exit tickets before they leave the class.

*** Supporting Students in Engaging in Developing and Using Models**
In this exit ticket students are explicitly prompted to think

Assessment Opportunity

Before day 2 of this lesson, review students' exit tickets. The exit tickets will provide valuable information about the kinds of ideas the students will bring to the consensus model and how much scaffolding you will need to provide in order to reveal gaps in the consensus model and motivate Lessons 7 and 8. Look for at least a couple of students to point out that (1) we are still not sure where the energy comes from, (2) we are still not sure why the battery or music player makes the coil into a magnet, and (3) we are still not sure why the forces are switching back and forth between pushes and pulls since it doesn't seem like anything is flipping orientation in the speaker. Note who is already considering these gaps and be prepared to call on these students to move the discussion forward on day 2. If nobody is noticing these gaps in the model, be prepared to use probing questions on day 2 to clarify students' explanations and reveal these gaps.

about the limitations of models. No model necessarily represents all ideas equally well; rather one model might be better at representing one idea, while another model might be better at representing another idea.

End of day 1

5. Compare models in a gallery walk. 13 MIN

Materials: science notebook

Do a short gallery walk. Present **slide G**. Tell students that during the gallery walk they will visit 2 to 3 other models with their small groups and write notes in their science notebook in response to the following prompts:

- one idea that you saw used in each model that you think may be useful for your class to use
- one difference you saw where you can argue that your group's model represents the concept, cause-and-effect relationship, or part of the system better

Set the timer for 5–6 minutes to give groups of students up to 2 minutes to view each of the models they want to visit. There will not be enough time for each group to view them all. You can assign groups to visit certain models or have them choose which to visit so long as each model is visited by several different groups during this time.

6. Build a consensus model in a Scientists Circle. 32 MIN

Materials: science notebook, chart paper, colored markers, colored pencils, sticky notes

Form a Scientists Circle for a Consensus Discussion. Have chart paper prepared at the front of the room. Ask students to bring their science notebooks to the Scientists Circle. The purpose of this discussion is to put the pieces together about what we've figured out about magnetic fields to build a class consensus model for explaining the at-a-distance forces in the speaker.

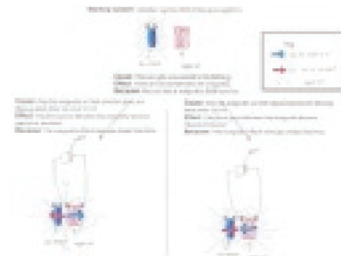
Prepare the Progress Tracker. Display **slide H**. In their notebooks, students should find a new two-page spread in their Progress Tracker section. Have students draw a three-box Progress Tracker to help the class come to an agreement about the evidence and what the class has figured out in words and pictures. This is the first time students have drawn a three-box Progress Tracker in this unit. Use **slide H** to orient students to this task.

First have students write in their Progress Tracker the question they have been trying to answer: *How can we use magnetic fields to explain interactions at a distance between the magnet and the coil?* Then ask students what evidence they have been working with to answer this question (e.g., iron filings, compasses, simulations, experiments with

*** Attending to Equity**
Not all students are comfortable being the "only one" who voices a disagreement or a potentially wrong idea. Ask students to think about what they heard their group members saying and ask the room if *their group members'* ideas are represented in the class discussion. This supports all students to share, to listen, to be heard, and to be represented.

magnets and other items). Below the question have them record this summary of the sources of evidence. Tell students that our consensus model might fit on one page or it may span several pages, and that is fine.

Remind students of discussion norms. Reinforce positive ways you heard students sharing ideas in small groups when they developed their models in the previous class. Highlight important ways to talk with one another, including frames for how to agree or disagree respectfully and how to push for justification. Encourage students that it's OK to share an idea they're not sure about or to disagree with a group's idea.*



Facilitate a Consensus Discussion. Display **slide I**. Ask students to offer proposals for what should go in the model, support or challenge these proposals based on evidence, and suggest modifications. During the discussion, ask students how to represent their ideas visually. On the whiteboard or on chart paper create a public representation of agreed-upon ideas as the class puts them together. We recommend creating a consensus model with multiple representations of the speaker system, as in the image.

Prompts for eliciting student proposals for what should go in the model

- What parts do we need to include?
- How can we represent the forces between the magnet and the coil of wire when the forces are repulsive versus when they are attractive?
- How should we represent the magnetic field?
- How should we represent both cause and effect for each of these relationships?

Prompts to ask students to support or challenge proposals

- What ideas are we in agreement about?
- Are there still places where we disagree? Can we clarify these?
- Who feels like your idea is not quite represented here?

Prompts for proposing modifications or coming to consensus with conflicting ideas

- How are these explanations similar? How are they different?
- How could we modify what we have so that we account for that evidence?
- Is there more evidence or clarification needed before we can come to agreement? What is that?*

Have students record the final representation of the class consensus model in their science notebooks. The model should incorporate the cause-effect relationships articulated by the class. You can annotate these relationships on the model or consider using a numerical or alphabetic labeling system to align the relationships on the poster we made to the relationships in the image.

*** Strategies for This Consensus Discussion**
At the end of this lesson set, the purpose of this Consensus Discussion is to build a common, class-level model to explain how magnetic forces cause vibration in the speaker, drawing on all the ideas learned in Lessons 1–5. The teacher's role is to prompt students to share what needs to be in the model, evidence they have to support their ideas, and how to represent it. Students should offer proposals, support or challenge their peers' ideas, and decide what we agree on. Suggested prompts are provided to help elicit, probe, and challenge student ideas to help them come to consensus during this discussion.

*** Attending to Equity**
The key ideas outlined here are suggestions for important ideas the model could include. It is important, however, to appropriate the words and ideas that your students use during this discussion and agree upon. Your class's ideas could be articulated differently and may include other ideas not listed here. Actively look for different ways students share and represent their ideas as an opportunity to communicate to your students that different ways of representing our thinking is valuable. These differences give the students an

Key Ideas

Purpose of the model: The purposes of this consensus-building activity are to (1) develop a shared visual language for representing the invisible parts of a system with a magnet and an electromagnet (including a magnetic field and magnetic forces) and (2) use this visual language to represent and explain cause-effect relationships that we have observed between a magnet and a coil of wire.

The model should include these key ideas:

- The coil of wire with a current has a magnetic field around it similar to the permanent magnet. The coil of wire is a magnet (electromagnet).
- There is an invisible space around the magnet and the electromagnet, and it shows what the direction of the forces would be on a test object in this space. This space is called a magnetic field.
- When the magnetic forces are primarily attractive between the permanent magnet and the electromagnet, the shape of the field is different than when the magnetic forces are primarily repulsive.
- Flipping either magnet so that the poles are alike or the poles are opposite will change the shape of the magnetic field (from attractive when the poles are opposite to repulsive when the poles are alike).
- Because of this magnetic field, the coil and the magnet can apply forces on each other that make them move without touching.

Additional Guidance

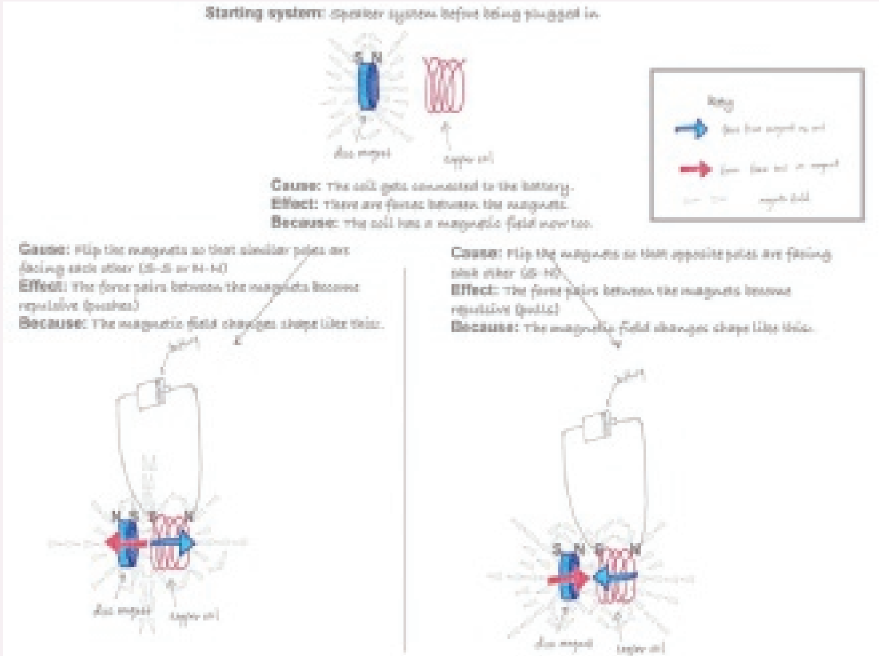
In a speaker, the coil (known as a "voice coil") sits nested inside the permanent magnet but not touching it. If the magnet and the coil touched, this back-and-forth movement would wear down the coil, causing the speaker to not function. Thus, having a small distance between the coil and the magnet is essential for a properly functioning speaker. Magnetic fields around the two magnets (the permanent magnet and the coil) make this movement possible without contact.

Have students record the final representation in their science notebooks, and keep the class consensus model in a public space. Your representation will look something like the image below, though representations can vary.

Question	Sources of evidence
How can we use magnetic fields to explain interactions at a distance between the magnet and the coil?	• Experiments in L2 with magnets and electromagnet • Iron filings demonstration • Compasses investigations • Computer interactive with magnetic fields

opportunity to think more deeply about their evidence and what the evidence supports or does not support.

What we figured out in words and pictures



Remain in the Scientists Circle to take stock of questions we've answered. Display **slide J**. Have students take another look at the Driving Question Board (DQB). For answered questions, on the same card as the question, have students record an answer they think they have. Then have students move the answered questions to a different section of the DQB (labeled "Questions we have answered"). If there is time, give students a chance to add any new questions they have to the DQB now.

Navigate to the next class and forecast the assessment. Say, *It looks like we have really made progress on answering our questions about the speaker! I wonder if we can apply our ideas to explain a related phenomenon we haven't investigated or explained yet. Let's plan to take our model for a test drive in an individual assessment next class.*

End of day 2

7. Assessment

20 MIN

Materials: *Figuring out the doorbell*, doorbell with cover removed

Introduce the assessment. Show **slide K**. Read the scenario on the slide.

Say, *In the unit so far, we have identified how the parts in a speaker work together to make the speaker move. I found another system that also produces sound, and it has some of the same parts in it that the speaker does. This new system is a doorbell. It is powered by a battery and has copper wire coils in it too. Let's see if using our approaches for thinking about systems and cause and effect can help us figure out how this system produces sounds.*

Additional Guidance

Before class, pry the cover off of the doorbell to reveal the components inside. Hold the doorbell up at the front of class or pass it around so that students can see it up close. Spend no more than two minutes introducing the doorbell so that students have sufficient time to take the assessment before turning their attention to gaps in the model.

Say, *When you hook a battery up to the system, the hammer arm moves and hits the bell.* As you say this, point to the hammer arm on the photo on the slide or push the hammer arm into the bell so that the bell produces sound. Then say, *The bell makes a sound when this happens. We are going to ask you some questions about the doorbell to give you a chance to demonstrate what you know about the parts of this system and figure out what is going on here using what you know.*

Pass out *Figuring out the doorbell* to each student. Say, *The speaker has a coil of wire that we can connect to a battery. It also has a magnet. But what about the doorbell? I brought a magnet near the doorbell when it was not connected to the battery, and I felt a pull, or an attractive force.* At this point, you can take a magnet and stick it to the doorbell, as in the photo on **slide L**.

Then say, *But is this because there is a permanent magnet, like in the speaker? Or is there another explanation? In Lesson 2, we noticed that metals like iron also produce attractive forces when they interact with a magnet. Let's think about what we could do to decide between these two explanations for the magnet being attracted to the doorbell.*

Additional Guidance

If you have time, consider using the following questions to help students make connections to earlier units. If you use these extra questions, allocate extra time for the assessment.

3. Extension from 8.1 Broken Things

The doorbell is a designed system. Its purpose is to produce sound. Think back to the Broken Things Unit and answer the following questions:

- What happens to the bell when the hammer strikes it? What can you say about the contact forces and deformation happening between both objects during this collision?

4. Extension from 8.2 Sound Waves

Think back to the Sound Waves Unit and answer the following questions:

- What happens to the bell as the hammer strikes it (and after it strikes it) that **causes** that collision to produce a sound?
- In a typical doorbell, the bell that produces the sound is located inside the house. How does a person in the house hear the sound coming from the bell? How does the sound move across the space between the bell and their ears?

Attending to Equity

This assessment is designed to provide multiple modalities in which students can express their competence. Encourage students to use drawings, symbols, and words to articulate their ideas. Accept explanations that use any combination of scientific and everyday words, but use the opportunity to remind students of the scientific words so that they can begin to acquire and try on this new vocabulary.

Supporting Students in Three-Dimensional Learning

This three-dimensional midpoint assessment is designed for students to express their competence in applying science concepts using science practices in the context of crosscutting concepts.

- **Question 1** requires students to apply ideas about electromagnets, magnets, and magnetic fields using the practice of hypothesis framing (part of SEP1: Asking Questions) in the context of cause and effect (CCC1).
- **Question 2** requires students to apply ideas about forces, magnets, and magnetic fields using the practice of diagrammatic modeling (part of SEP2: Modeling) in the context of systems and systems models (CCC3).

8. Identifying Gaps in What We Know

10 MIN

Materials: pen, sticky notes, Consensus Model poster

Highlight gaps in the model. Display **slide M**. Say, *We used our ideas to answer a lot of questions and to explain something totally different—a doorbell! But can we explain the speaker yet? What don't we know? What are the gaps in this model? Turn to a partner and discuss the questions on the slide:*

- *How is our model different from the speaker system?*
- *What else do we need to know in order to explain the speaker?*

Give students several minutes to discuss. Then ask pairs to share out. As students make suggestions, write question marks in a different color marker on the consensus model.

Suggested prompts	Sample student responses
How is this model different from the speaker?	*The speaker doesn't have a battery.* *Nothing flips around in the speaker.*
What are the gaps in the model?	*We aren't sure why plugging into the battery makes the coil of wire into an electromagnet.*
What else do we need to know in order to explain the speaker?	*Is the music player the same as the battery? What is it doing differently?* *How do we get pushes and pulls in the speaker if nothing is flipping around?*

Additional Guidance

If your students need more scaffolding to notice the gaps in the model, use the following prompts.

- Why does plugging in the battery make the coil into an electromagnet?
- Does the speaker have a battery?
- Why do we get repulsive forces between the two magnets in certain cases and attractive forces between them in other cases?
- Are the magnets in the speaker flipping back and forth?
- What change in the speaker system is causing that effect?

Look for students to struggle with these questions. If students put forward a theory, ask, *What evidence do you have to support that?*

9. Navigation

15 MIN

Materials: 1 pad of arrow-shaped sticky notes, Class Consensus Model poster

Motivate adopting an energy perspective to help fill gaps in our model. Say, *For the past few lessons we've been thinking about forces and magnetic fields. We agree that forces in a magnetic field are important for explaining why a magnet can move a speaker without touching it. But we have a lot of gaps that we can't explain.*

Present **slide N**. *Two ways that we have been talking about the interactions in this system are forces and energy transfer. Let's think back to the phenomenon of the windows moving to the bass in the Sound Waves Unit.*

Use the photo on the slide to remind students about the phenomenon of the windows and the sound from the truck from *Unit 8.2: Sound Waves*. Then say, *We can say that the speaker pushes the air with a force, and the particles in air collide with neighboring air particles, which puts a force on that other air, and eventually collides with the window. Or we can say that the sound wave transferred energy from the speaker across the air to the window. These are two different ways of thinking about the same system, and they are both correct.*

Say, *When scientists are having trouble explaining interactions in one way, like forces, sometimes they will look at another way of explaining those interactions, like energy. From the beginning, we have been thinking about this system in terms of forces, but also in terms of energy. So let's reconsider our magnet system from an energy perspective. Let's see what additional insights, questions, and ideas for investigations that might help us generate.*

Switch to **slide O**. Have students turn to a partner and discuss the question on the slide, Where in the speaker system do we have evidence of energy transfer because something starts moving or stops moving? After a couple of minutes, have partners share out.

As students share ideas, focus students on ideas about energy flow by probing their responses with questions like these:

- Where was the energy transferring from before it went into _________?
- Where did the energy go after it left _________?

Students might talk about how the energy leaves the speaker system as sound, or they might talk about where they think the energy comes from. At this point, both are productive. The goal of this navigation is to get students thinking in terms of energy flows.

Add energy flow to our consensus models. Switch to **slide P**. Say, *Scientists use models to keep track of energy flows in a system. Let's look back at the consensus model that we made here. Where do we know energy is being transferred between parts of the system?* Pass out small sticky notes shaped like arrows. Have students spend some time with a partner (or in table groups) identifying places on the model in their Progress Trackers where they think energy is transferring and labeling those with an arrow sticky. Warn them that they should be prepared to share their ideas and justify them.

After a couple of minutes, bring the class back together and ask for students to volunteer an idea. As students share, hand that student another sticky note in the shape of an arrow, and ask them to use the sticky to indicate on the consensus model where they think the energy is transferring and in what direction. Push students to justify their ideas.

Students should identify at least 3 of the following:

1. energy transferring into the coil or speaker cone (or both)
2. energy transferring into or out of the permanent magnet

3. energy transferring from the battery
4. energy transferring into or out of the magnetic field

Motivate the carts investigation in the next lesson. Once students have identified these places on the model, say, *It looks like we have some pretty good ideas about how we are thinking energy transfers in this system. We know from the Sound Waves Unit what happens to the energy after it transfers out of the speaker. We also know that energy must be transferring into the coil because it moves. We have some ideas and some questions about energy transfer in the magnetic field and the magnet and maybe the battery. Let's think about energy transfer a little more, and maybe this new framing can help us fill some of the gaps we identified in our model.*

Use a hypothetical system with two magnets to get students thinking about energy transfer. Say, *OK, so we want to investigate energy in a magnetic field. Let's think about what cause-effect relationship we might need to investigate. Imagine we have two magnets. What do I need to do with those magnets, a cause, to get energy to transfer into them?*

Look for students to suggest moving the magnets around. Ask, *What would our evidence of energy transfer be?* Look for students to suggest motion. Say, *OK, so if the effect we want is to see motion, we want to know what changes we have to make to the system to get that motion.*

Record our ideas on an exit ticket. Display **slide Q**. Say, *Let's do a quick exit ticket. Write down some of your ideas about what changes we need to make to this system of two magnets to get the effect we would expect if energy transfers. Consider the changes you would make if the magnets were oriented so the forces were attractive and if the magnets were oriented so that the forces were repulsive. Use cause-and-effect language to articulate your ideas.*

Assessment Opportunity

This exit ticket is designed to assess students' application of the cause-and-effect sentence starters to make predictions about the interactions between magnets when distance or orientation of the magnets change. An ideal response might look like this:

- When we bring the magnets close together when the forces are attractive, then we will observe energy transfer so that they move toward each other and stick together.
- When we bring the magnets close together when the forces are repulsive, then we will observe energy transfer so that they fly apart.

The prediction itself is useful as a tool for motivating the activity in the next lesson. You will refer to some of what you saw in the student responses at the launch of the next lesson, so make sure to read through a representative sample of them at least for this purpose.

But the most important thing in using this response for individual student assessment is not the content of the prediction, but the students' comfort with using the cause-effect sentence starters to formulate their predictions. If students are still struggling to apply this structure to their predictions correctly without a more-explicit scaffold, consider returning to the Lesson 1 slides introducing the use of the fill-in-the-blank scaffold to describe cause-and-effect relationships. Insert these slides at the beginning of Lesson 7 and use a familiar system (e.g., a falling cell phone) to practice making predictions. You might also consider using a video of a Rube Goldberg machine to practice describing cause and effect.

SCIENCE LITERACY: READING COLLECTION 3

Gravity and Earth

1 **The Moon Matters**
2 **Why Don't Satellites Fall?**
3 **Gravitational Lensing**
4 **Solar Winds**

Literacy Objectives

✓ Use reading to explain how gravity can act on bodies in space.

✓ Read to describe how satellites orbit Earth.

✓ Using examples from reading compare how gravity and magnetism act on small and large objects.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 5–6.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an argument for gravity or magnetism as the stronger force in response to the reading.

Instructional Resources

Student Reader

Collection 3

Science Literacy Student Reader, Collection 3
"Gravity and Earth"

Exercise Page

EP 3

Science Literacy Exercise Page
EP 3

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 5: How does the magnetic field change when we add another magnet to the system?
- Lesson 6: How can we use magnetic fields to explain interactions at a distance between the magnet and the coil?

Standards and Dimensions

NGSS Performance Expectation MS-PS2-3: (Building toward) Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

Disciplinary Core Ideas PS2.B: Types of Interactions; **PS3.A:** Definitions of Energy

Science and Engineering Practices: Asking Questions; Constructing an Explanation

Crosscutting Concepts: Cause and Effect; Systems and System Models

CCSS

English Language Arts

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

W.8.1: Write arguments to support claims with clear reasons and relevant evidence.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

magnetic field **orbit**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Exercise Page

EP 3

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations.

MONDAY

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Forces at a Distance unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *In "The Moon Matters," you will learn how the force of gravity allows the moon to make changes on Earth, even though the two space objects never touch.*
    - *In the second selection, you'll read about how gravity causes objects in space to stay in orbit.*
    - *"Gravitational Lensing" explains how gravity enables people to see objects far away in space, far beyond what we can see through even the most powerful telescopes.*
    - *In "Solar Winds," you'll read about a scare tactic that is used to sell products that protect people from solar winds.*

- Distribute Exercise Page 3. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to argue for whether gravity or magnetism is the stronger force.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete. (*Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

WEDNESDAY

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
How is gravity involved in the interactions between Earth and its moon?	*Gravity holds the moon to Earth and Earth to the moon. This causes the tides.*
Is the moon a satellite, a star, or a planet?	*It's a natural satellite because it orbits around the planet Earth. A planet orbits around the sun. The sun is a star, which is a ball of gas giving off energy in the form of light and heat. So the moon is not a planet or a star.*
What makes a satellite stay in orbit?	*A satellite, natural or made by people, stays in orbit because of Earth's gravity pulling it straight down and its motion in a straight line perpendicular to the force of gravity. The two acting simultaneously keep the satellite in an orbit.*
How are Earth's magnetic and gravitational fields different and the same?	*Both result in a force at a distance. Both fields get weaker the farther away something is.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What is a magnetic field?	*the space around a magnet that will push and pull on certain things*
If Earth is a giant magnet, how could it repel harmful objects?	*Any charged object that arrives via solar wind, for example, will be deflected by the magnetic field around Earth.*

Refer students to the Exercise Page 3. Provide more specific guidance about expectations for students' deliverables due at the end of the week.

- *The writing expectation for this assignment is to develop an argument for gravity or magnetism being the stronger force.*
- *In the selections, you read about how Earth's gravity and magnetic fields interact with other objects in space without touching them.*
- *Think about what you read and know about gravity and magnetism. Think about their effects on small objects and objects in space.*
- *Decide whether gravity or magnetism is the stronger force. Make a list of examples and evidence that supports your decision.*
- *Write an argument to make your case. Start by stating your position, and then support it with reasons and evidence.*
- *Make your argument persuasive with great examples so your readers will come to agree with you. A great argument will have very clear and persuasive evidence.*

Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 3

4. Facilitate discussion.

FRIDAY

Facilitate class discussion about the reading collection and writing exercise.

The four reading selections expand on understanding the effects of noncontact forces in everyday examples of how the noncontact forces of gravity and magnetism act on a huge scale on objects in space.

Student Reader

Collection 3

Pages 20–21 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "The Moon Matters"?	*It describes the moon and how it is important.*
	It discusses the moon's effects on Earth.
	It explains Earth's gravitational pull on the moon and how this impacts Earth.
How does the gravitational pull on the moon compare to how gravity works in your everyday life?	*Gravity holds the moon in orbit. Gravity holds things in place on Earth.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 20–21 **Suggested prompts**	**Sample student responses**
What causes high tide and low tide on Earth?	*As Earth rotates in regular patterns, different parts of Earth are exposed to the face of the moon. The greater gravitational pull when facing the moon forces large bodies of water to change shape.*
Do the phases of the moon affect tides?	*When the moon is full, high tides are at their highest and low tides are at their lowest because the sun, the moon, and Earth all line up.*
Why are people able to predict times for high and low tides?	*Tides are dependent on the 24-hour rotation of Earth. By calculating when the moon is facing a part of Earth, people can predict the tides.*

Pages 22–23 **Suggested prompts**	**Sample student responses**
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first selection was about the gravitational pull of Earth's natural satellite. This selection expands on that to include an understanding of how gravity keeps human-made or artificial satellites in orbit.*
How does gravity keep a satellite in orbit?	*The satellite would travel in a straight line if were not for Earth's gravitational force.*
How did people figure out how to launch satellites and keep them in orbit?	*They observed natural satellites and used mathematical calculations to figure out what it would take to keep an artificial satellite in orbit.*

Pages 24–25 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third article, "Gravitational Lensing"?	*It explains how people can observe gravitational pulls to see farther into space than we can see with telescopes.*
What is a gravitational lens?	*It is the distortion and magnification of light from distant galaxies caused by gravity, like looking through a giant magnifying glass.*

SUPPORT—Some students may benefit from a further discussion of how gravitational lenses allow people to see clusters and galaxies that telescopes cannot see.

CHALLENGE—Have interested students research the invention of artificial satellites, the first of which launched in the late 1950s. Have them include the many uses of artificial satellites today that have changed so many aspects of life on Earth. Ask them to share their findings with the class.

EXTEND—Have students watch a video that shows how the moon's gravity causes tides.

EXTEND—Have students watch a video to show how Earth's magnetic field works to protect against solar winds.

CHALLENGE—Challenge students to find out about gravitational wobble, which is a tool for identifying distant planets. Ask them to share their findings with the class.

Pages 26–27 Suggested prompts	Sample student responses
What is the general purpose of the fourth article, "Solar Winds"?	*This selection demonstrates what misinformation can sound like on the internet.* *This article explains that although solar winds are dangerous, Earth's magnetic field protects the planet from them.*
What are solar winds?	*a constant stream of charged particles and magnetic clouds coming from the sun into space at high speeds*
Why are solar winds dangerous?	*If the material carried by solar winds reached a planet's surface, its radiation would do a lot of damage.*
How does Earth's magnetic field protect the planet from solar winds?	*It serves as a shield around the planet, pushing the winds away so they stream around the planet.*
How does the last selection relate to the other selections in this collection?	*It tells more about how noncontact forces work on a large scale.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 3, students should present an argument for whether gravity or magnetism is a greater force.

Use the rubric provided on the Exercise Page to supply feedback to each student.

How does changing the distance between two magnets affect the amount of energy transferred out of the field?

Previous Lesson

We recorded the cause-and-effect relationships that we figured out in Lessons 2-5. Then we constructed a class consensus model to explain these relationships and how they work together to produce the movement we saw between the magnet and the electromagnet. We still had a lot of gaps in our model that we want to investigate, mostly around the electromagnet. How does it work? And how does it produce both pushes and pulls when it is connected to a music player instead of a battery?

This Lesson

Investigation

1 DAY

We plan and carry out an investigation using a cart on a track to determine how changing the distance between two magnets affects the energy transferred in a magnetic field between them. We explain how the data collected from this investigation support or refute our initial hypotheses. We construct explanations based on evidence to support the claim that changing the distance between two magnets affects the amount of energy stored in and then transferred out of the field for both attractive and repulsive forces.

Next Lesson

We will ask questions about the energy flow coming from a computer and a sound generator vs. the energy flow coming from a battery. We will vary the volume and frequency of sounds being produced and observe the effects on a speaker, a lightbulb, and a wire coil. We will gather information on how changes in the electric current (the cause) result in changes to a magnetic field (the effect) within the speaker system.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Plan and carry out an investigation using a cart on a track to determine how changing the distance between two magnets affects the amount of energy transferred from the field between them.

Develop an explanation using results from the investigation to explain the interactions and behavior of the cart system using ideas about forces and potential energy.

What Students Will Figure Out

- When two magnets have repulsive forces on them and they are pushed together and then released, kinetic energy is transferred into the magnets as they move back apart.

- When two magnets have attractive forces between them and they are pulled apart and then released, kinetic energy is transferred into the magnets as they move back together.
- Changing the distance between two magnets changes the amount of potential energy stored in the magnetic field and the amount of energy that can be transferred out of it (as kinetic energy).

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Share initial ideas about what changes we would be able to detect between two magnets as we moved them closer and further apart.	A-B	
2	12 min	**PLAN THE INVESTIGATION** Work in small groups to develop and document an investigation plan.	C-E	*Hypotheses and Variables*, *Data Table and Procedure*
3	12 min	**CARRY OUT THE INVESTIGATION** Work in small groups to carry out the investigation plan.		*Hypotheses and Variables*, *Data Table and Procedure*, Energy transfer in fields investigation
4	10 min	**DEVELOP EXPLANATIONS** Develop an explanation for their results, which applies to the design of the store-bought speaker and how the behavior and interactions of this system compared to those of another system.	F	*Making Sense of Your Investigation Results*, chart paper, markers
5	3 min	**NAVIGATION** Motivate looking more closely at the music player in the next lesson.		consensus model from Lesson 6
				End of day 1

Lesson 7 • Materials List

	per student	per group	per class
Energy transfer in fields investigation materials	• calculator	• track and a meter stick taped as shown in the materials preparation section • ceramic magnet mounted to a cart with mounting putty • ceramic magnet mounted to a brick with mounting putty • stopwatch or electronic timer (e.g. on a tablet or phone).	
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Hypotheses and Variables* • *Data Table and Procedure* • *Making Sense of Your Investigation Results*		• chart paper • markers • consensus model from Lesson 6

Materials preparation (30 minutes)

Online Resources

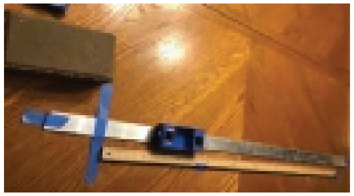
Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

If students have not completed these two prior units, Unit 8.1 *Why do things sometimes get damaged when they hit each other?* (Broken Things Unit) and Unit 8.2 *How can a sound make something move?* (Sound Unit), before this unit, you will need to modify *Making Sense of Your Investigation Results* to remove or replace questions 2 and 3.

Energy transfer in fields investigation

- **Group size:** 3-4
- **Advanced preparation:** This lesson will reuse some equipment that was used in Unit 8.1 *Why do things sometimes get damaged when they hit each other?*
  - First, prepare a track on a flat, smooth tabletop (testing station) for each group by taping a piece of aluminum track and a meterstick parallel to it as shown in the image here. Lay a piece of tape perpendicular across the track so that it lines up with 0 cm on the meterstick.



  - Second, mount one magnet to a cart and one magnet to a brick for each group:
    - Orient two ceramic disc magnets so that the same pole on each is facing the other, producing repulsive forces between them.

- Place a small piece of mounting putty on one of the ceramic disc magnets and stick the putty to the bumper of the cart, thereby attaching the magnet. Place the cart on the track.
- Place a small piece of mounting putty on the other ceramic disc magnet and stick this to the end of a brick so it is at the same height as the magnet on the cart when the cart is on the track. Place the brick and magnet so the front side of the magnet is in line with the edge of the tape that is lined up to the 0 cm mark on the meterstick.
- Test to make sure the magnets produce repulsive forces when pushed against each other. Adjust the position of them as needed so that the face of one aligns with the face of the other when the one on the cart is pushed all the way up against the one on the brick.

- Third, provide a stopwatch or electronic timer (e.g., on a tablet or phone) for each group. And provide a calculator for each student (or have them use their own).
- **Storage:** Except for the tape that is used, the rest of the materials can be stored and reused indefinitely. Store the used and leftover mounting putty in a sealed container or bag to prevent dirt or dust build up on it.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

The change in motion of the cart when it is released is evidence that a nonzero net force must have been applied to the cart.

The kinetic energy the cart receives after being released comes from energy stored in the magnetic field as nonzero net forces from the field are applied to the cart when it is released. It is not energy that is related to collision with any other objects in the system, unlike prior work students have done in previous units, including these:

- Unit 6.2 *How can containers keep stuff from warming up or cooling down?* (Cup Design Unit)
- Unit 8.1 *Why do things sometimes get damaged when they hit each other?* (Broken Things Unit)
- Unit 8.2 *How can a sound make something move?* (Sound Unit)

In the Broken Things unit, students determined that energy can be stored and released in the deformation of objects during elastic collisions. In this lesson, students start to develop the idea that energy can be stored and then released from the magnetic field. Such energy is related to the relative position of the objects to one another.

There are three sets of related ideas that students are likely to bring to the table in their responses to the questions on *Making Sense of Your Investigation Results*. These ideas are parts of the following DCIs:

- PS3.A A system of objects may also contain stored (potential) energy, depending on their relative positions.
- PS3.B: When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.
- PS3.C: When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Where We Are NOT Going

Though students know from their prior work in the Broken Things unit that bigger changes in motion are a result of either larger net forces on an object or more individual smaller forces added up over a distance, it is not important that students recall this distinction in this lesson. It is hoped that students will start to connect a change in the amount of force applied from the system as an intermediate mechanism that can account for their results. Lesson 9 will help students connect these ideas together and will also introduce how forces in the magnetic field between objects transfer potential energy into and out of a field as the position of the objects in the field change relative to one another.

1. Navigation

8 MIN

Materials: science notebook

Share ideas from exit tickets in previous lesson. Present **slide A.** Use the text on the slide to remind students that they responded to this question in their previous exit tickets. Say, *I read through your exit tickets where you made predictions about energy transfer between two magnets as we move them closer together or further apart. It sounds like we should try to collect some firsthand evidence for these ideas using some real magnets. Let me show you some of the equipment we can use to design an investigation around some of the ideas you raised.*

Introduce the equipment available for the investigation. Present **slide B**. Read the text on the slide to introduce some of the equipment for this investigation. Have students turn and talk with a partner for one to two minutes about the prompt on the slide before asking students to share out their ideas with the class. Follow up on their initial ideas if they don't raise the idea that the distance you hold the magnets from each other before you release the cart will affect the results.

Suggested prompts	Sample student responses
What would you expect to see happen when you bring the cart with the magnet on it close to the magnet on the brick and then release it?	*We will see the cart move down the track.* *The cart might fly down the track if you brought it close enough.*
Why?	*The forces on the magnet attached to the cart would push it to the right.* *Energy transferred into the magnet on the cart from the field would push it to the right.*
Would you get the same result no matter how far away you held the cart?	*No. It depends on how far away you are.* *It might go further when you get the magnets closer.* *It might not move at all if you release the cart when the magnets are really far apart.*
Why?	*There is a bigger push on the cart the closer you bring the magnets together.* *There would be more force on the cart the closer the magnets are when you release the cart.*

Say, *I am hearing a lot of ideas about the distance between the magnets, ideas about how much force is applied to the cart, and ideas about how much energy would be transferred through the system. Let's think about how all these ideas connect. Let's try to form some hypotheses about the interactions and behavior of this system that connects some of these ideas together. Then we can use this equipment to test those hypotheses.*

2. Plan the investigation. 12 MIN

Materials: science notebook, *Hypotheses and Variables*, *Data Table and Procedure*

Orient students to creating a hypothesis. Remind students that it is often useful to create a hypothesis before planning the details of an investigation. This means you will need to develop

1. a proposed mechanism that you want to test (theory, explanation, or model) and
2. a cause-and-effect relationship that you would be able to observe if the proposed mechanism were supported.

Show **slide C**. Have students turn to two blank pages in their science notebooks. Hand out a copy of *Hypotheses and Variables* and *Data Tables and Procedures* to each student and have students add this to the two pages in their notebooks.

Then ask, *What is our explanation about what will happen to the energy transferred out of the field when we push the magnets together and then let go? In other words, what do we think is going on?*

Look for students to suggest that when we push the magnets closer together, more energy will be transferred out of the field. Remind students that this is our explanation about what is happening, so we don't need to be able to observe the energy directly. An explanation is often about invisible interactions.

Show **slide D**. Remind students that the next part of the hypothesis is a prediction that we can actually observe. Divide the class into groups of three or four students each. Have students work with their group to develop and record their hypotheses on *Hypotheses and Variables*. Watch for students using changes in movement as the effect they predict they will observe when the cart is released, since speed is one factor that is related to the amount of kinetic energy an object has.

After a couple of minutes or once some groups complete their hypotheses, pause all groups and show **slide E**. Tell students that they have at least 10 minutes with their small groups to document their plan as outlined on the slide and that after everyone has the plan documented, as you will collect this as part of what you want to assess for how they plan their investigation. After they do this they should go back to their lab station to collect their data, where they will have only an additional 12 minutes to carry out their plan.

Present trade-offs in data collection approaches. Emphasize that with the limited time available for data collection, groups will have to consider some trade-offs in what data they plan to collect. Say something like, *We know that having more data makes us more certain. But because time is limited, there are some trade-offs to consider. One possibility is to use the time available to test a lot of different values for your independent variable. Another possibility is to use the time available to conduct many repeated trials for a smaller number of values for your independent variable. But you probably won't have enough time to do both. So decide in your group which is more important to you so you can do that first. Structure your data table accordingly in case you get to collect only some of the data you hoped to get to during the allocated time.*

Additional Guidance

If any groups finish their investigation plan early, they can call you over to check it, which will give you an opportunity to provide feedback to each group for anything obvious you see they overlooked as well as provide a staggered staging for having the groups of students go to their lab stations at different times (when they have a plan ready).

3. Carry out the investigation. 12 MIN

Materials: Energy transfer in fields investigation, science notebook, *Hypotheses and Variables*, *Data Table and Procedure*

Monitor lab work. Float among groups to monitor student communication, collaboration, and coordination among group members. Support students as needed as they collect data and calculate the speed of carts.

Additional Guidance

Here is a sample set of results from one trial for three different values of the independent variable that were tested (gap distance between the magnets):

Initial gap between magnets (cm)	Distance the cart traveled (cm)	Cart travel time (sec)	Average speed of the cart (cm/sec)
0	65	2.5	26.0
5	20	1.2	16.7
10	8	0.8	10.0

Supporting Students in Making Connections in Math

Beginning in 6th grade students should have experiences with describing unit-rate relationships such as constant speed. If students struggle to set up their calculations, ask them to explain the units of speed they expect. You can provide context by asking what it means when we describe the speed of a car, bus, or train in miles per hour.

4. Develop explanations. 10 MIN

Materials: science notebook, *Making Sense of Your Investigation Results*, chart paper, markers

Develop individual explanations. Regroup students back in their regular seats. Display **slide F** and hand out a copy of *Making Sense of Your Investigation Results* to each student to work on individually. Emphasize that this is also part of their thinking you want to assess. Collect these before the end of class.

Assessment Opportunity

Making Sense of Your Investigation Results is fundamental in developing the following student ideas:

1. Energy transfers from the magnetic field into the magnets to make them move.
2. Energy transfers out of the field and into the magnets for both attractive and repulsive forces, even though the direction of the movement is different.

Collect this handout at the end of the lesson and check that students are developing these ideas. If necessary, spend time at the beginning of Lesson 8 or 9 reinforcing these ideas by going through *Making Sense of Your Investigation Results* together as a class.

Alternate Activity

If students have not completed units 8.1 and 8.2 before this unit, you will need to modify *Making Sense of Your Investigation Results* to remove or replace questions 2 and 3. If you modify *Making Sense of Your Investigation Results* due to prior instruction that students have had, other than the Broken Things unit or Sound unit, you will need to make sure these ideas are developed in another way, either through guided discussion or direct instruction, before putting the pieces together in Lesson 9.

5. Navigation

3 MIN

Materials: consensus model from Lesson 6

Summarize what we don't know in order to motivate the next lesson. Point to the arrow for energy transfer between magnets in the consensus model that the class made in Lesson 6. Say, *Today we added to our understanding of this model by getting a better idea about how energy is transferred between any two magnets and the field between them. But in the speaker, even if energy can be transferred to and from the field, where did the energy from the field come from in the first place?*

Discuss this question briefly as a whole class. Look for students to name the music player as a source of energy. They may also mention that they think the energy is getting transferred through the wires.

Say, *It sounds like we think that the music player might be providing the energy stored in the field. But we haven't been using a music player in our experiments with electromagnets. We have been using a battery. Is a music player providing the same thing to the speaker as a battery?* Give students a half a minute to consider this. If you have a few minutes left, take responses from students. Accept all answers without indicating if they are right or wrong.

Say, *Since we have all of these ideas about how both the music player and a battery provide energy to an electromagnet, let's plan to investigate both of these energy sources further next time.*

Make sure you have collected science notebooks, which contain *Hypotheses and Variables*, *Data Table and Procedure* and student investigation plans in them, as well as collecting *Making Sense of Your Investigation Results*, which is still a loose piece of paper, before students leave class.

Assessment Opportunity

Look for the following in students' notebooks (*Hypotheses and Variables* and *Data Table and Procedure*):

- a hypothesis that addresses how changes in the distance between two magnets (cause) will result in differences in the amount of energy transferred to the cart (effect) when it is released
- distance (gap) between the two magnets identified as the independent variable
- speed of the cart after it is released identified as the dependent variable
- a data table with recorded measurements of distance traveled and travel time from when the cart is released to when it stops moving
- a data table organized to record more than one value for the independent variable

- a data table organized to record more than one trial for the value of the independent variable tested
- calculation of average speeds for each trial or averaged speeds across multiple trials for each value of the independent variable tested

Leave feedback in the form of noticings and wonderings in the student notebooks. Return these to students at the start of the next lesson. Examples of such feedback include statements like these:

- *I noticed that you identified distance as your independent variable. I am wondering if you can be more specific in words and/or diagrams to help make your thinking visible about how you will determine or measure the distance you will be changing.*
- *I noticed that you created a data table to record travel time for each trial. I am wondering if this was the time it took the cart to travel across a certain finish line or if it was the total travel time from when it started moving to when it stopped moving.*

Look for the following in *Making Sense of Your Investigation Results*:

- **In response to question 1**
  - Changing the distance between the magnets causes a change in the amount of energy transfer in the field between them.
  - a statement saying whether this supports or refutes their initial hypothesis
- **In response to question 2**
  - Potential energy was stored in the magnetic field between the two magnets.
- **In response to question 3**
  - a statement saying that the evidence supports the claim
  - reasoning that explains that the evidence shows that changing gap distance affects how loud a sound is produced when magnets are released to come back together
  - additional reasoning (optional) that explains that since loudness is based on the amplitude of vibration and bigger-amplitude vibrations require or carry more energy, the change in the distance must have transferred a different amount of energy into the production of the sound

Leave feedback in the form of noticings and wonderings in the student notebooks, and return these to students at the start of the next lesson. Examples of such feedback include statements like these:

- *I noticed you mentioned differences in energy transfer in response to question 1. I am wondering if this supports or refutes your hypothesis and why.*
- *I noticed you discussed changes in the forces you felt in both systems as you pushed the cart into or toward the launcher. I am wondering which part of the system feels most like a spring. What evidence do you have that this part of the system could be storing potential energy as a spring does?*

ADDITIONAL LESSON 7 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.8.1: Write arguments to support claims with clear reasons and relevant evidence.

In this lesson, students make a written claim about energy transfer between objects in a magnetic field and the magnetic field. They should support claims with logically organized evidence from their investigation. Students will also evaluate the reasonableness of another written claim based on sufficiency and accuracy of the available evidence.

Students' ability to make and justify claims is supported by the procedures of this lesson. Small groups of students develop hypotheses and investigation procedures for testing their hypotheses, including determining how and what type of data to collect. In this way, they are thinking about what kind of evidence and reasoning will support or refute their hypotheses which describe cause-effect relationships.

In their ELA classes, students have experience in determining claims, evidence, reasoning, and counterclaims made by authors in reading materials and in organizing written arguments based on their understanding of complex text. They may know how to use an argument template to make a claim followed by supporting evidence and reasoning, counterclaims or rebuttals, and a conclusion.

If students are struggling to make or support claims, help them clarify their thinking by asking open-ended questions such as these:

- What patterns in data do you notice?
- What interactions did you notice?
- What do you understand from the data you collected?
- How do your data support or refute your hypothesis?
- What cause-effect relationships are evident?
- How is all the evidence and reasoning tied together?
- Why is the claim important?

Supporting Students in Making Connections in Math

CCSS.MATH.8.F.B.4: Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (*x, y*) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

In this lesson, students will determine the rate of change from tabular data recorded during their investigation. They will calculate and interpret this rate as the speed of a cart moving along a track. As they analyze their calculations, it is important for students to realize that as the initial gap between magnets increases, the resulting speed of the cart decreases.

A common error in rate (speed in this case) calculation is made when students incorrectly apply an algorithm. It may be helpful to ask them to describe the expected units to help them determine how to correctly set up their problem.

Performing calculations by hand with decimal numerals can also lead to errors. Students can use calculators to determine cart speed since this math concept is not important to understanding the scientific principles in this lesson.

How does the energy transferred from a battery to a wire coil compare to the energy transferred from a computer to a speaker?

Previous Lesson

We planned and carried out an investigation using a cart on a track to determine how changing the distance between two magnets affected the energy transferred in a magnetic field. We constructed explanations based on evidence to support the claim that changing the distance between two magnets affects the amount of energy stored in and transferred out of the field between them for both attractive and repulsive forces.

This Lesson

Investigation

3 DAYS

We ask questions and form hypotheses about how the energy flow coming from a computer and a sound generator compares to what is coming from a battery. We vary the volume and frequency of sounds being produced and observe the effects on a speaker, a lightbulb, and a wire coil. We argue that to produce different sounds, the computer is changing the strength or amount of the electric current it provides, the direction of that current, and how rapidly it changes that current. We gather information and use it to help explain how changes in the electric current produced by the computer (the cause) result in changes to a magnetic field (the effect) within the speaker system.

Next Lesson

We are ready to start putting the pieces together to explain the speaker. We will add to our list the cause-and-effect relationships that we figured out in Lessons 7 and 8. Then we will construct a classroom consensus model to explain these relationships and how they work together to produce the patterns of movement we see in the speaker.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Ask questions and carry out investigations to answer questions about how the pattern of energy flow compares in different systems using a speaker, a wire coil, a lightbulb, a battery, and a computer.

Critically read scientific text to gather evidence to explain the differences in the electric current produced by the computer (the cause) that results in a changing magnetic field within the speaker system (the effect).

What Students Will Figure Out

- More batteries in the circuit give more current, which transfers more energy, and results in stronger forces.
- Electric current changes direction when you flip the battery in a circuit.
- Electric current from a music player can change direction.
- The frequency of the changes in current determines the pitch of the sound (previous idea from the Sound Unit).
- Current that flips direction causes the poles of the electromagnet to flip.
- When the poles flip, the direction of forces (attractive vs. repulsive) flips in the field produced by the electromagnet.

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION AND PREPARING TO INVESTIGATE TWO SYSTEMS** Discuss different systems from an energy perspective to identify how they could help us figure out what a battery vs. a computer provides a speaker, a wire coil, and a lightbulb to get them to function.	A	
2	8 min	**EXPLORE CONNECTING THE LIGHTBULB TO THE BATTERY** Work in small groups to explore how to produce light from an incandescent lightbulb using batteries and wires.	B-D	Day 1: Battery and incandescent bulb investigations
3	7 min	**MAKING SENSE OF RESULTS** Discuss the results from the previous investigation as a whole class and introduce ideas about complete circuits and electric current.	E-F	
4	8 min	**DEMONSTRATION OF VOLUME EFFECTS ON SPEAKER AND LIGHTBULB** Demonstrate how changing volume of sound production in the computer app affects the light produced by an incandescent light and discuss the results as a whole class.	G-H	Day 1: Volume investigation
5	7 min	**EXPLORE HOW TO GET THE LIGHTBULB TO SHINE BRIGHTER** Work in small groups to explore how to produce brighter light from the same lightbulb as before, using batteries and wires.	I	ruler, incandescent lightbulb (1.5 V, 100 mA), 2 stickers or pieces of tape, 2 D-sized batteries, Day 1: Battery and incandescent bulb investigations
6	7 min	**MAKING PREDICTIONS OF FREQUENCY EFFECTS ON THE LIGHTBULB** Discuss results from the previous investigation as a whole class and individually form questions and make predictions about the response of the lightbulb to changes in sound frequency (pitch) in the computer app.	J-K	1 separate piece of notebook paper

End of day 1

Part	Duration	Summary	Slide	Materials
7	5 min	**NAVIGATION** Share the questions, ideas for investigations, and predictions that students generated last time.	L-M	exit tickets
8	15 min	**CHANGING FREQUENCY ON LIGHT SOURCE DEMONSTRATION** Demonstrate how changing frequency of sound production in the computer app affects the pattern in the light produced by the incandescent lightbulb and a compass in its magnetic field and discuss the results as a whole class.	N-O	Day 2: Frequency investigations
9	9 min	**EXPLORING HOW TO GET THE LED TO LIGHT UP** Work in small groups to explore how to produce light (of different colors) from a single LED using batteries and wires.		Day 2: Battery and LED investigation
10	8 min	**FORMING HYPOTHESES** Work in small groups to develop two hypotheses to test with the LED.	P	
11	10 min	**CHANGING FREQUENCY DEMONSTRATION WITH THE LED** Demonstrate how changing the frequency of sound production in the computer app affects the pattern in the light produced by the LED.		Day 2: Frequency investigations
				End of day 2
12	10 min	**NAVIGATION** Share which hypotheses were rejected and supported from the previous day. Create and complete a two-column chart for "What we figured out" and "Questions we have".	Q-R	chart paper, markers
13	23 min	**READING: MUSIC TO MY EARS** Set up the reading by highlighting questions that remain. Students read the text with a partner and discuss questions along the way.	S	*Music to My Ears*
14	10 min	**BUILDING UNDERSTANDINGS DISCUSSION** Lead a Building Understandings Discussion with the class to summarize and synthesize Key Ideas from this lesson.	T	
15	2 min	**NAVIGATION** Navigate to the next lesson by summarizing the Key Ideas from the lesson that will be used in the Putting the Pieces Together lesson that follows.		*What is electric current?* (optional)
				End of day 3

Lesson 8 • Materials List

	per student	per group	per class
Day 1: Battery and incandescent bulb investigations materials		• ruler • incandescent lightbulb (1.5 V 100 mA) • 2 stickers or pieces of tape • 1 D-sized battery	
Day 1: Volume investigation materials			• 3.5 mm mono audio plug to alligator clips • small speaker (4 Ohm/3W) • incandescent lightbulb (1.5V 100 mA) • computer with internet access and aux cord audio output jack • Turn it Up! (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
Day 2: Frequency investigations materials			• wire coil and binder clip • 3.5-mm mono audio plug to alligator clips • small speaker (4 Ohm 3W) • incandescent lightbulb (1.5V 100mA) • 1 small compass • 8 alligator clips • computer with internet access and aux cord output jack • Hitting the High Notes (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • amplifier with power cord and male-male 3.5 mono audio plug • large speaker (4 Ohm • 60W) • 1 bicolor LED • computer with internet access and aux cord output jack

	per student	per group	per class
Day 2: Battery and LED investigation materials		• materials bin with: 1 ruler • 2 D-size batteries • 2 stickers or pieces of tape • 2 alligator clips • 1 bicolor LED	
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • 1 separate piece of notebook paper • exit tickets • Music to My Ears • What is electric current? (optional)	• ruler • incandescent lightbulb (1.5 V 100 mA) • 2 stickers or pieces of tape • 2 D-sized batteries	• chart paper • markers

Online Resources

Materials preparation

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make a few additional copies of *What is electric current?* for students who want to learn more. This reading, however, introduces concepts (electrons) beyond the middle school gradeband, and should be reserved for students who have additional questions and want to know more after completing the base reading for this lesson: *Music to My Ears*.

Day 1: Battery and incandescent bulb investigations

- **Group size:** 3-4
- **Advanced preparation:** Place the following in a materials bin for each group:
  - 1 ruler with slot down the middle of it to serve as a battery holder
  - 2 stickers or pieces of tape (to attach the exposed ends of the wires from the light bulb to the ends of the battery terminals)
  - 1 incandescent lightbulb (1.5 V, 100 mA).
  - 1 D-sized battery (to start with)

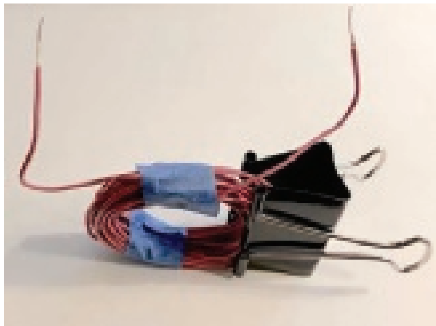
- **Investigation setup:** Students do two investigations with this equipment. Give groups an extra D-sized battery to use when they start their second investigation. Collect these extra batteries from them at the end of the period so that they are not in the bins for the next class of students to use in their first investigation.
- **Safety:** Remind students that the lightbulb is fragile. The lightbulb will burn out (the filament in it will melt) if it is hooked up to more than 2 batteries in series.
- **Storage:** Except for the batteries, stickers, and tape, the materials can be stored and reused indefinitely. Batteries last longer when kept in the cold for long-term storage, such as a freezer. But they also don't deliver as much current when cold, so make sure they are at room temperature when students are using them.

Day 1: Volume investigations

- **Group size:** Whole class
- **Advanced preparation**
    - **Prepare a materials bin.** Place the following in a bin to reuse across classes:
        - 3.5 mm mono audio plug to alligator clips
        - 1 small speaker (4 Ohm, 3W)
        - 1 incandescent lightbulb (1.5V, 100 mA)
- **Practice:** Do a dry run of the related investigations, making sure to test that the computer app works as intended. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) This video demonstrate this investigation as well as providing a backup to show students instead of doing a live interactive demo if you need it. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- **Safety:** Shorting out the circuit can prevent the speaker from playing sound or the lightbulb from lighting up. Make sure that exposed wires don't touch each other. Also make sure that when you hook up the alligator clips to the speaker, they don't touch the metal casing.
- **Storage:** Except for the batteries, the materials can be stored and reused indefinitely. Batteries will eventually lose their charge after repeated uses.

Day 2: Frequency investigations

- **Group size:** Whole class
- **Advanced preparation**
    - **Assemble a wire coil:** Take one piece (25 to 50 feet long) of 18 gauge magnet or bell wire and use it to make a wire coil with 40+ loops and ~3-inch diameter. Tape the coils together so they don't fall apart. Strip both the ends of the wire to expose the bare copper. Clip a large binder clip to the coil to serve as a stand to hold it upright on a table.
    - **Prepare a materials bin.** Place the following in a bin to reuse across classes:
        - 1 wire coil and binder clip (see image)
        - 13.5-mm mono audio plug to alligator clips
        - amplifier kit



        - 1 amplifier
        - 1 power cord
        - 1 male-male 3.5 mono audio plug
    - 1 small speaker (4 Ohm, 3W)
    - 1 large speaker (4 Ohm, 60W)
    - 1 incandescent lightbulb (1.5V, 100mA)
    - 1 bicolor LED
    - 1 small compass
    - 8 alligator clips
  - **Practice:** Do a dry run of the related investigations, making sure to test that the computer app works as intended. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) These three videos demonstrate this investigation as well as providing a backup to show students instead of doing a live interactive demo if you need it. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- **Investigation setup**
  - Set up a demonstration table where all students can see it (e.g., the center of the room).
  - Set up a second table to put the laptop or computer on. Make sure the amp power cord can reach a powerstrip from this table. This extra table will ensure that your use of the laptop doesn't bump the table the compasses are on. Use the extra alligator clips to test to make sure the two tables are close enough to bridge the gap between them.
- **Safety**
  - Don't turn the volume knob on the amp to maximum when the speakers are hooked up. Loud noises can damage hearing. Only turn the volume knob up to max when the wire coil or LEDs are hooked to it.
- **Storage:** The materials can be stored and reused indefinitely.

Day 2: Battery and LED investigation

- **Group size:** 3-4
- **Advanced preparation:** Place the following in a materials bin for each group:
  - 1 ruler (with slot down the middle of it) with a slot in it to serve as a battery holder
  - 2 D-size batteries
  - 2 stickers
  - 2 alligator clips
  - 1 bicolor LED
- **Safety:** Remind students that the LEDs are fragile.
- **Storage:** The new material in this investigation (the LEDs) can be stored and reused indefinitely.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

Current is first introduced in 4th grade in NGSS. The DCIs in the foundation box of this PE (4-PS3-4), state that *"Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light."*

This lesson builds off these ideas by having students construct a circuit with a lightbulb in it to provide evidence that both the battery and the electronic computer device are sources of electrical energy for the system, and the circuit provides a path for that energy to reach the wire coil.

The lesson connects the emergence of magnetic forces in a field around an electromagnet to the current flowing through the coil in the system.

In later lessons, students will start to find evidence that the patterns in how electric current changes in a circuit correspond to patterns in the forces produced, including a relationship between the strength of the current and the strength of the force produced by the electromagnet. This is directly related to the middle school DCI for PS2.B:

- Electrical and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

This lesson extends the development of this idea a bit further to help students also develop evidence that the direction of a current corresponds to the direction of the forces produced by an electromagnetic field. This idea is needed to explain the change in polarity of the electromagnet that occurs in the speaker system that causes it to vibrate.

Where We Are NOT Going

When students change the number of batteries in their circuit, they are changing the voltage provided to the circuit. This is a change in the potential energy for the circuit. The current is a resulting outcome of what travels through that circuit. Such current involves the movement of electrons. The same is true for the computer or music player, which changes the voltage provided to the circuit, and the resulting current that travels through the circuit is an emergent property of that voltage and the resistance of the devices hooked up to it (the load on the circuit). Voltage and resistance, however, are not target DCIs for this grade band. Refer to the energy flowing through the system in terms of electric current only to keep the description of energy flow in the system consistent and accurate.

You can drive some speaker systems using current that flows in only one direction by applying what is known as an *offset voltage* to the circuit. The pattern in such current flow is analog but varies up and down over time without ever reversing direction. Such systems are beyond the scope of phenomena explored in this unit.

1. Navigation and Preparing to Investigate Two Systems

8 MIN

Materials: None

Make a circle for the investigation. Have students organize their chairs in a circle around a space they can all see, such as a low table in the middle of the room. They should also be able to see the consensus model and slides from their chairs.

Additional Guidance

When students typically meet in a Scientists Circle, it is beneficial for them to sit near new people rather than their small-group members. And it is critical that everyone can see one another. But today, emphasize to students that this isn't a standard Scientists Circle. Rather, it is a staging space for planning and making sense of multiple small investigations with their group members. That necessitates that they can talk with them as needed while also referencing what they see at the demonstration table in the middle of the circle. This means that they will need to sit near their group members and that they need to make this circle into two rows to make a tighter circle in order for everyone to be able to see the demonstration table. Students will leave and return to this circle many times between investigations. Keep the chairs in this configuration for all your classes over the next two school days. You will need students to do those investigations in a space outside the circle. Here are two options for that:

- Have students relocate to meet (standing) around a desk that the chairs are no longer around to conduct each of their investigations.
- Have students relocate to meet at an assigned lab table.

Alternate Activity

If your materials are limited or you are struggling to get the three whole-class investigations to work using the equipment you have, you may use the three videos available. This is not ideal since doing the demonstrations will provide students firsthand evidence for these phenomena. Therefore, make every effort to get these demonstrations to work as they are shown in the videos. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Connect to the energy-related work from the prior lesson. Reinforce the ideas students developed in their *Making Sense of Your Investigation Results* responses. Say, *We've been considering this system from an energy perspective to make progress on some of our questions. I've read through the explanations you turned in from the last lesson. It sounds like you figured out some important things about energy transfer in a field, that it is stored in the magnetic field before being transferred into the magnets and that this is true when the forces are attractive and also when they are repulsive, even though the direction of the motion is different. This seems like an important piece of the puzzle for figuring out how energy transfers through the entire system to the speaker. But there are more parts of the system that we had argued might involve energy transfers.*

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**

In previous lessons students designed many aspects of the investigations they carried out and had a relatively long amount of time to do them. In the very short investigations students do in this lesson, the planning aspect is not the main focus of their work. And they have a very short amount of time for each investigation. This shift in focus for this lesson is because the goal of these investigations is different. Students are carrying out these investigations in order to produce data to serve as the basis for evidence that is framed around trying to figure out answers to a series of questions the class will narrow in on at different points in the lesson. These explorations do not require students to follow a predetermined procedure. In order to accomplish the goal of each investigation in a short amount of time, students will need to attend to how they communicate, cooperate, and take turns with their group members.

Ask students to summarize what those remaining parts were. Students should say the connection (the wires) between the source and the electromagnets in both systems (the system with the battery and the system with the computer).

Say, *Let's continue analyzing those other parts of the systems we have been working with from an energy perspective and see what else we can figure out.*

Show **slide A**. Give students a minute and a half to discuss with a partner the questions on the slide. Then have students share their discussions as a whole class.

Suggested prompts	Sample student responses
What evidence do we have that connecting the wire coil to a battery provides it energy to do something?	*It moves when it's connected to a battery and a permanent magnet is brought near it, but it doesn't move when it's disconnected from the battery.* *It attracts and can be attracted to other things with iron in them when a battery is connected to it.* *It can make compass needles move when connected to a battery.*
What are some other systems that need to be connected to a battery (or batteries) in order to do something?	*flashlights, toys, remote controllers, phones, electric toothbrushes, tablets or laptops*

Prepare to investigate different systems. Ask about one of the items students mentioned—a flashlight or another device that produces light. Ask them what they will see a lightbulb do when a flashlight is switched on and there is a working battery in it. And ask them how this will compare to when the battery is dead in the flashlight. Students will say that the lightbulb will produce light (become a light source or flow) in one case and won't do this in the other case.

Hold up an example of the small lightbulb that students will be using. Say something like, *Here is a small lightbulb similar to ones that can be found in some flashlights. If a battery is dead, it won't be able to light up a bulb like this. But if the battery is working it should be able to light up a bulb like this. Let's plan on using this lightbulb as a kind of energy detector in the two different systems we have been considering—the battery-powered electromagnet and the computer-powered music speaker. We will swap a lightbulb for various parts in both systems to try to figure out what is going on with the energy flowing through the system under various conditions. To prepare to do that let's build a data table to record five different investigations we are going to do with a lightbulb in these different systems. Each investigation won't take very long, and you will be able to complete each one much quicker than a typical lab. Three of the investigations will be in small groups. You will have less than five minutes to complete those over the next two days. Let's set up that data table across two new pages of your science notebook now so we will be ready to record our discoveries and move quickly to the next investigation.**

2. Explore connecting the lightbulb to the battery.

8 MIN

Materials: Day 1: Battery and incandescent bulb investigations, science notebook

Prepare to investigate two different systems. Show **slide B**. Have students set up their science notebook as shown on the slide. Say, *You figured out how to connect a battery to a wire coil to provide it energy to become an electromagnet. So, how does that work? How does a battery provide energy to other things connected to it? Let's explore one example of that first. How can you connect a battery to a lightbulb in order to get it to provide energy to the bulb? Write that question in the first row of your table to investigate with a small group.** Show **slide C** to reference this question and show students where to add it in the data table:

- How can we connect a battery to a lightbulb in order to provide it energy?

Introduce the equipment students will use. Show **slide D**. Point out that the photo shows one way to use a ruler as a battery holder, which can keep the battery from rolling and also free up your hands to work with other parts of the system. Point out where the equipment bins and stations are for the investigations. Assign students to lab groups. Encourage students to try different ways of hooking up the battery if the first thing they try doesn't work. And remind students as they work with it that the lightbulb is quite fragile.

Additional Guidance

Let students figure out how to connect the lightbulb to the battery on their own. You may see students trying to connect both wires to one side of the battery at first. That is fine; let them try different things and fiddle around. If you see a group stumped in the last two minutes, you could encourage them to have a different person in the group try hooking up the wires a different way and another group member to check in with groups that may have gotten it to work.

Do the investigation. Set the timer for 4 minutes. When it goes off tell students they have one minute left and have them push the materials to the side and complete their data table row now if they haven't yet. Reset the timer for 1 minute and signal students when it goes off.

* Supporting Students in Developing and Using Patterns

You may want to be even more explicit in the rationale for why using a piece of equipment from a different electrical system (a light bulb) might help us identify cause-and-effect relationships in the electromagnet systems. You could say something like, *Often when we are trying to figure out cause-and-effect relationships in a system, it can be helpful to look for patterns across similar systems. Since we are looking at our system through an energy perspective, it could be useful to also look at other systems that are very similar from an energy perspective and see what patterns we notice. So looking for energy flow patterns when we use a lightbulb in place of a wire coil or speaker may help us see patterns that help us better identify possible cause-and-effect relationships across all systems.*

3. Making Sense of Results

7 MIN

Materials: science notebook

Make sense of the results. Have all students bring their notebooks up to the circle again to sit around the whole-class demonstration table. Ask students to share what they did to get the battery to provide energy to the lightbulb.

Students will say that they had to connect each of the two wires from the bulb to the two different sides of the battery.

Introduce the ideas of a *complete circuit* and *electric current*. Connect the word *circuit* to the word *circle*. Ask, *How is a circuit similar to a circle?* Students should respond that both are continuous—no beginning or end.

Say, *Making this sort of connection to both ends of the battery so that energy can get to the lightbulb is called making a* complete circuit. *It is called a complete circuit because it provides a continuous path for* electric current *to flow. The electric current transfers energy from the battery to the lightbulb when it is hooked up to the battery.*

Instruct students to add labels to their own diagram they made from the previous investigation to indicate the path for electric current to flow through the battery to the lightbulb.

Additional Guidance

All that is needed right now is for students to indicate any sort of path through or over the wires that the electric current could flow. This will likely lead students to include one or more arrows in their diagram. This may lead students to wonder if current is something that flows through both wires or just one wire. They may also wonder if it has a direction to the flow. If students raise these questions, encourage them to represent their own ideas about how they think electric current may flow in the system using part or all of the path of the complete circuit.

Brainstorm whether this form of energy transfer is happening from the computer to the speaker. Show **slide E**. Have students discuss the related questions with 1-2 elbow partners near them for two minutes and then ask them to report out.

Suggested prompts	Sample student responses
Do you think the music player is providing the same thing to the speaker when it produces different sounds?	*(Accept all answers.)*
How could connecting the lightbulb to the headphone output jack (AUX) wires from a computer help us figure that out?	*If it lights up, then it is also providing an electric current.* *If it doesn't, then that would tell us that maybe it isn't providing an electric current.*

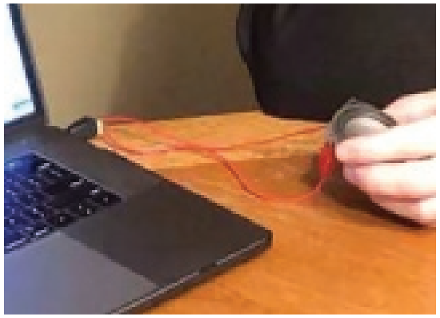
Emphasize that it seems like we have a new question we can investigate using the lightbulb. Show **slide F**. Give students a moment to record this related question:

- Is the computer providing electric current to the speaker to produce sounds?

4. Demonstration of Volume Effects on Speaker and Lightbulb

8 MIN

Materials: Day 1: Volume investigation, science notebook

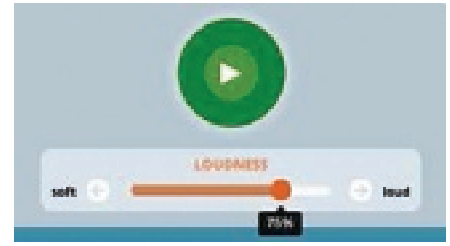


Carry out a whole-group interactive demonstration or investigation. Explain that you are hooking up a small speaker to the computer and checking to make sure that the sound app that we used before in the Sound Waves Unit is producing sounds before swapping the lightbulb into the system.

Hook a small speaker up to the headphone output jack, using the 3.5 mm mono audio plug to alligator clips adaptor.

Open the first sound simulation in the browser window. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Press "play" for the default loudness level on the app (75%) to play the first sound.



Once the speaker is playing the default sound, ask students what they expect they would feel the surface of the speaker cone do differently if you change the volume of the sound being produced.

Based on their work from the Sound Waves Unit students will predict that they will feel the surface vibrating and how far it vibrates will change (greater amplitude of deformation of the speaker for louder volume).

Ask a student volunteer to come up and lightly press the tip of their finger against the cone of the speaker and report what they notice as you increase and decrease the loudness control on the app.

Then pause playing the sound on the app. Explain that you are now going to hook up a lightbulb in place of the speaker.

Disconnect the speaker and swap in the lightbulb.

Ask another student to turn off the lights in the room. Play the same sound again from the app. Have students take a minute to record the explanation to the question we are wondering about for this investigation. This is in the second column of their T-chart.

After doing this, tell students that next you are going to increase and decrease the volume in the app. Ask students to turn and talk with a partner for 30 seconds about what, if anything, they think they will see happen with the lightbulb when you do this.

Bring students back together and then demonstrate what happens as you increase the volume in the app. Do the same for when you decrease the volume in the app. Ask students what they are noticing as you do both of these. Students will say that they notice the light from the lightbulb getting dimmer when the control for the sound volume is decreased and brighter when it is increased.

Make sense of the results. Show **slide G**. Give students a minute to record their discoveries. Then use the following prompts to help students connect their discoveries to new claims they can make related to the amount of energy in the electric current flowing through the circuit.

Suggested prompts	Sample student responses
How do you think what you see happening is related to the amount of energy being transferred by the electric current?	*The amount of energy being transferred by the electric current is changing.* *It is transferring more energy when it is trying to produce louder sounds and less energy when it is trying to produce softer sounds.*
OK, so if we are claiming that the increased brightness is caused by increased energy transfer through an electric current, what are some changes we could make in the previous battery and bulb system to test this?	*We could connect more batteries.*

Suggested prompts	Sample student responses
What do you expect to see happen if using more batteries ends up causing an increase in the amount of energy transferred through the electric current to the lightbulb?	*The lightbulb would get brighter.*
What do you expect to see happen if using more batteries doesn't cause any change in the amount of energy transferred through an electric current to the lightbulb?	*The lightbulb brightness wouldn't change.*
What do you expect to see happen if using more batteries causes a decrease in the amount of energy transferred through an electric current to the lightbulb?	*The lightbulb would get dimmer.*

Say, *It sounds like we have a new question we can investigate.* Show **slide H**. Have students record the related question in their notebooks:

- How can we change the amount of energy transferred by an electric current to a lightbulb?

As students are adding the new investigation question to their notebooks, add an extra battery to each group's set of supplies.

Additional Guidance

There is an upward limit on how much current the lightbulbs you are using can handle. Exceeding that current limit will cause the filament of the lightbulb to melt and the lightbulb will no longer work. Two 1.5 V batteries connected end to end will not exceed that energy limit, but three 1.5 V batteries connected end to end will. This is why you are providing only one extra battery to each group for the next investigation.

5. Explore how to get the lightbulb to shine brighter.

7 MIN

Materials: Day 1: Battery and incandescent bulb investigations, science notebook, ruler, incandescent lightbulb (1.5 V, 100 mA), 2 stickers or pieces of tape, 2 D-sized batteries

Show **slide I**. Tell students that you updated their supplies they can use.*

Do the investigation. Set the timer for 4 minutes. When it goes off tell students they have a minute left and should push the equipment to the side and complete their data table row now if they haven't yet. Reset the time for 1 minute and signal students when it goes off.

*** Attending to Equity**
Use the additional prompt on this slide to emphasize the importance of coordinating taking turns in the actual messing about with the materials across each of these investigations—which is an important aspect of working collaboratively in any lab but could be easily overlooked when the investigation is relatively short like the previous one and this next one.

6. Making Predictions of Frequency Effects on the Lightbulb

7 MIN

Tell students that there will be yet another short exploration they will do after this one for this lesson, again working with a lightbulb, so that they can plan how to swap turns in each investigation.

Materials: science notebook, 1 separate piece of notebook paper

Make sense of the results. Have students briefly share what they discovered.

- Students will say that more batteries does provide more energy to the lightbulb through an electric current, but you have to connect the batteries in a certain orientation in order to get that to happen, otherwise you get no energy to the lightbulb (and probably no current).

Say something like, *OK, I want to know what these results tell you about what was happening when the computer app was hooked up to the speaker and the lightbulb when we changed the loudness control on it. Take out a piece of notebook paper to use as an exit ticket to record your individual thinking related to this question I want you to consider first.*

Show **slide J**. Give students a couple of minutes to write their responses to the following question (shown on the slide): *What is changing in the electronic music player system when you increase the volume of the sound being produced? Use the results of your investigations so far to explain your thinking.* Then pause the work on the exit ticket and have students flip their paper over. Assure them that they can return to this in a moment.

Say, *I want us to talk a bit about some related phenomena so I can find out your individual ideas about them on your exit tickets too.*

Connect to students' prior work in the Sound Waves Unit. Say, *The app we used in the last investigation changed only the volume of the sound produced. But we've used other versions of that app before in our investigations we did in the Sound Waves Unit. Those other versions of the app let us change other things about the sound being produced besides how loud it was. What other thing were we able to change about the sounds being produced using those other versions of the app?*

Students will probably suggest how high or low the pitch of the sound is (or its frequency).

Additional Guidance

If students didn't complete the Sound Unit before this unit, you can rephrase this question like so: "What other ways do sounds differ besides how loud they are?" This may generate multiple ways of describing sound quality and characteristics, but one of those is likely to be pitch.

Say, *I'd like to know more about your ideas. Let's take a moment to capture your individual thinking to summarize where we are and where we should head next.*

Show **slide K**. Have students turn their exit tickets back over and add their responses to questions B through D.

- B. What new question would it make sense to investigate next?
- C. How could we reuse the speaker and the lightbulb to investigate this question?
- D. What do you predict you would see, feel, and hear using each of these?

Give students four minutes for this. Then have them turn in these exit tickets.

Assessment Opportunity

Student responses to question B in the exit ticket will be an opportunity for you to assess their abilities to ask questions to investigate in class. Here is an example of a question students might ask: How would the lightbulb appear or respond or shine when we change the pitch or frequency of the sound produced by the computer?

Have students share their responses to the last three questions with the class. There will be a large consensus around the responses to question B and the ideas for investigations for question C. Students will say that we should put the LED in place of the speaker and change the frequency of the sound produced and this will help us investigate a question like “How does changing the frequency of the sound produced affect the electric current in the system?” Expect a diversity of predictions in the responses to question D.

Encourage a sense of wonder and anticipation around needing to investigate the predictions to question D next time and leave students on a cliff-hanger.

End of day 1

7. Navigation

5 MIN

Materials: science notebook, exit tickets

Stay in a circle. Remember to keep the class chairs organized in a circle around a space they can all see, such as a low table in the middle of the room. They should sit next to their small-group lab members and they should also be able to see the consensus model and slides from their chairs.

Look back on where we left off and where we were headed next. Show **slide L**. Ask students to recap the question we were wondering about when we ended the last time and what ideas we had for investigating that question. Press students to connect the work we have been doing over the last two lessons to understand part of the system from an electric current perspective.

Suggested prompts	Sample student responses	Follow-up questions
What did we figure out about the relationship between the volume of a sound produced by the speaker and the electric current in the system?	*More energy goes to the speaker when there is louder sound.* *The energy provided by the electric current flowing through the circuit must increase.*	*How does that energy get from the computer to the speaker?* *How did our work with a lightbulb help us see that?*
What new question(s) did that raise for us at the end of last class?	*What is happening to the electric current in the system when a high pitch vs. a low pitch sound is being produced?*	*What new ideas did that raise for how this might be happening?*

Suggested prompt	Sample student responses	Follow-up questions
	Does the current change in the system in some way when low frequency vs. high frequency sounds are being produced by the computer?	
What sort of investigation did we think it would make sense to do next with the speaker and lightbulb?	*We wanted to see what happens to a speaker vs. a lightbulb when we hook up both to an app and change the frequency of sounds produced.*	

Say, *Let's add this question to our notebook*. Show **slide M**. Have students record the related question in their notebooks:

- How does the electric current compare for different frequency sounds the computer tries to produce?

8. Changing Frequency on Light Source Demonstration

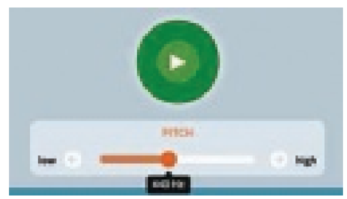
15 MIN

Materials: Day 2: Frequency investigations, science notebook

Carry out a whole-group, interactive demonstration or investigation.

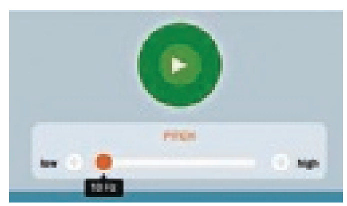
Hook up the speaker to the aux cord adaptor as you did in the last demonstration. Again, remember the tips you learned about in the video to ensure the alligator clips aren't shorting out (e.g., touching the metal casing of the speaker rather than only the leads on the speaker).

Close the previous simulation browser window. Open a new browser window for the second simulation. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)



Adjust the default pitch on the sound app to 440 Hz. Press "play" and turn up the volume on the keyboard to maximum.

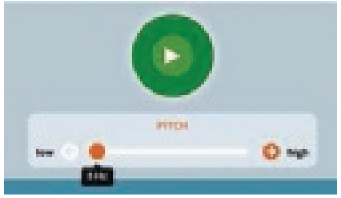
Ask a student volunteer to come up a lightly press the tip of their finger against the cone of the speaker and report what they notice as you decrease the frequency control on the app to 10 Hz. Students will say that they notice it pulsating. They may even say it feels like it is moving back and forth 10 times a second.



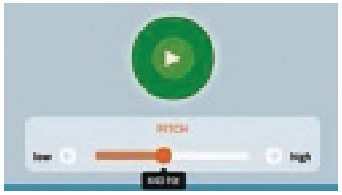
*** Supporting Students in Developing and Using Patterns**

Students are looking for patterns in rates of change in the flickering or blinking of the light. What they are looking for is that the rate of blinking pattern changes with frequency. Lower frequency = lower rate of blinking. But they are not trying to find exact numerical relationships in this flickering. Avoid trying to count or calculate the number of blinks per second in the lightbulb as a class as this will produce questions that cannot be resolved with grade-level mathematics.

The number of flickers per second will actually be twice as frequent as the number of times reported by the sound app. This is due to the structure of the alternating electric current produced by the computer, Then say that you are going to drop the frequency to 3 Hz. Remind students that sounds at these frequencies are not detectable by our ears. This is an idea they developed in their previous work in the Sound Waves Unit. Drop the frequency to 3 Hz and ask a student to again describe what they feel when they lightly press the tips of their finger against the cone of the speaker. They will say that they notice it pulsating even slower. They may even say it feels like it is moving back and forth 3 times a second.



Reset the frequency to 440 Hz and then pause the sound playing before disconnecting the speaker.



which is a sine wave, where the peaks and troughs represent the maximum current flow in opposite directions. This understanding is at a university level and is intended only for the teacher.

Swap the lightbulb into the circuit in place of the speaker. Have a student volunteer turn off the lights. Play the sound at 440 Hz. Ask students what they notice. They should say the lightbulb lights up.

After doing this, tell students that you are going to decrease the frequency of the sound the app produces through its electric current. Ask students to describe what they notice as you drop the frequency to 10 Hz. Students should say that it appears to be flickering.

Ask students to describe what they notice as you drop the frequency to 3 Hz. Students should say that is appears to be flickering even more slowly.

Ask students to describe what they notice the lightbulb doing as you slowly increase the frequency. Students will say that its flickering is getting more rapid. Keep increasing it until some students say that it appears to no longer flicker. Ask students why that is. Some students will suggest that it might be flickering too fast for us to see.

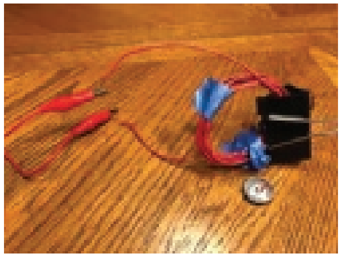
Tell students that just like how our ears can detect sounds with vibrations that are changing between only a certain frequency range, our eyes can detect only certain changes in the rate of flickering, and the upper limit of this is 80 Hz, or 80 flickers per second, and that anything more rapid than this would appear to us as unchanging.*

Use the prompts below to make sense of the flickering or blinking pattern in terms of rates of changes occuring in electric current.

Suggested prompts	Sample student responses
How do you think what you saw happening at low frequencies is related to the amount of energy being transferred by the electric current?	*The amount of energy being transferred by the electric current is changing.* *It is repeating in a pattern—energy is being transferred and then not and then it is being transferred and not, over and over again.* *It is like a switch flipping electric current on and off over and over again at a really rapid rate.*
OK, so we are claiming that the cause of the flicker is related to a changing electric current flowing through the circuit, which is changing the amount of energy that gets to the bulb. But would this also be changing the amount of energy transferred to and from the magnetic field in our speaker coil?	*Accept all predictions.*
We've used compasses before to detect changes in the magnetic field. Do you think we would see anything happening to a compass that we put near a copper wire coil hooked to this system?	*Accept all predictions.*

Say, *Let's wait to summarize our results from what we saw with the lightbulb so we can see what happens when we have a coil and a compass in the magnetic field as well.*

Continue the whole-group, interactive demonstration or investigation.



Hook up the wire coil you made earlier to the aux cord adaptor using alligator clips. Use the binder clip to make sure the coil stands upright on the table. Connect each of the two ends of the wire coil to a chain of 3 alligator clips (6 alligator clips total) so that each chain reaches one of clips on the 3.5 mm mono audio plug to alligator clips adaptor plugged into the computer you are running the app from. These two chains of alligator clips will provide you additional distance between the computer and the coil, to prevent two possible sources of interference.

1. Put the computer on a different surface than the table that the coil is on. This is so that when you play or pause the sound generator app on the computer, you won't end up bumping or pressing on something in contact with the table with the coil.
2. The two chains of alligator clips will allow you to keep the coil more than 3 feet away from the computer while still connecting it to the audio output jack. The computer produces its own magnetic field that will interfere with the results from the coil if it is too close to it (less than 3 feet away).

Though you will use the simulation that you used in the previous investigation, make sure it is paused right now. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Place a compass 1 inch from the bottom of the coil. Adjust the orientation of the coil so that its loops are parallel to the direction the north pole of the compass is facing.

Make sure all students can see the compass. To do this you may want to ask the front row of students to sit or kneel so the back row can see. Remind those students that since we are going to be looking for changes in how the compass responds, we want to make sure to not disturb the table by making contact with it.

Ask two students near the compass to describe the direction that the compass needle is currently pointed. Students will say that it is facing north (or close to north).

Bring up the simulation that you used in the previous investigation. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) It should still be set to the last frequency you explored with it (3 Hz). Press the "play" button on the app.

Ask students what they observe the compass doing. Students will say that the needle bounces back and forth, but it is hard to tell if it is due to the initial movement of the compass (when students moved it around) vs. something from the field.

Ask students to predict what would happen if you drop the frequency further to 1 Hz (1 vibration per second). Students will say that the needle is bouncing back and forth at a slower rate. They may also say it travels further in each bounce.

Test it at 1 Hz.

Now test 2 Hz and 3 Hz (again). Ask students to explain how the bounce back and forth compares now. Students will say that the needle is bouncing back and forth at a different rate than 1 Hz and that it doesn't travel as far with each bounce.

Ask whether the needle overshoots its original position it was facing before we started the app or whether it comes back to its original position. Students will likely say it is hard to tell.

Decrease the frequency to 1 Hz and ask students to describe how far the needle travels and then pause the simulation and compare where the needle settles. Students are likely to say that the needle appears to overshoot its initial stationary position.

Additional Guidance

Don't highlight the fact that you are using higher-gauge (thicker-diameter) copper wire than students used before. If students, however, ask why we aren't using the same wire coils we used earlier, follow their line of questioning with further questions to help them capture their thinking to add to the DQB, such as these questions:

- *Do you think the thickness of the copper wire used in a coil affects the magnetic field it will produce?*
- *What other things about the structure of the coil might affect the magnetic field as well?*
- *These are really great questions that could serve as ideas for possible future investigations. Can you add these to a sticky note and then put it on our DQB and/or Ideas for Future Investigation poster so we don't forget to follow up on them in future lessons?*

Make sense of the coil results. Show **slide N**. Allow students to complete the row of their T-chart using the results of testing we did with both the lightbulb and the coil and compass with the sound generator at different frequencies.

After taking a couple minutes to do this, ask students to share their thinking. Then ask them to summarize what we now know about the relationship between the rate of vibration of the needle and the rate of current changes in the system.

Students might say that when one increases the other also increases and when one decreases the other also decreases.

Additional Guidance

It is only important to establish a qualitative relationship between frequency of current changes and frequency of changes in compass direction. It is not necessary nor time efficient, at this point, to figure out whether that relationship is directly proportional or not.

Raise the question about what exactly is causing the pattern of vibration in the compass in the field. Display **slide O**. Have students turn and talk with a partner for a couple of minutes, then have students report out.

Expect there to be disagreement or controversy about whether cause A or cause B is producing the effects they noticed. Emphasize that this is another important thing we just discovered, namely that there are two possible ways that the magnetic field could be changing and that we should record both possibilities. Write these two possibilities on the board and have students add these to their explanation and solution section of their T-chart for the fourth row it. The updated table entry in students' notebooks might look like this now:

- We know the electric current is changing over time, and the rate of change is related to the rate of vibration.
- What we don't know is how its current is changing, but there are two possibilities:

  A) The current is repeatedly switching from on to off (at a certain frequency).

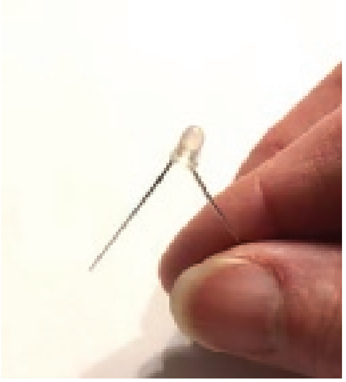
  B) The current is repeatedly doing something else that causes the needle and speaker to move back and forth (at a certain frequency).

9. Exploring How to Get the LED to Light Up

9 MIN

Materials: Day 2: Battery and LED investigation, science notebook

Introduce a new energy detector. Say, *I have another kind of lightbulb, an LED, that responds differently to electric current than the other one we used. The previous lightbulb was an older type of lightbulb, an incandescent. Where have you seen different kinds of lightbulbs used in your own homes? Do they function differently?* Accept all student responses.



Hold up the LED lightbulb students will be using. Say, *If we are going to use this new lightbulb as a detector for electric current in the speaker system, we have to first figure out how its response compares to an incandescent lightbulb in a system we already know. So your immediate goal with your small group is to take this LED and figure out how to provide it electric current to get to light up. Feel free to use all the equipment, including both batteries left in your materials bin. I want someone in your group to raise their hand when you get your lightbulb to light up and leave it lit up until more groups get to the same point. If you are stuck after 3 minutes, look around to other groups that have a hand raised and go over to see what they did.*

Launch the investigation and watch for a point to pause it. Have students start working with their groups. Once you see half the groups with hands up, pause the small-group work. Ask students to look around the room to see what they notice as you turn off the room lights. When you do this students will report out that some of the lightbulbs appear to be shining different colors (some look redder and some look greener). Act surprised about this and say, *I know I gave everyone the same type of lightbulb.*

Say, *You have a new task now. Borrow a lightbulb that is shining a different color from what your bulb did and hook it up exactly like you did before. Let's try to figure out what is going on with these lightbulbs.*

Resume the investigation. Give three extra minutes for this and then pause the small-group work.

Additional Guidance

These bulbs will shine red if they are connected one direction in the circuit, but if you flip the bulb, it will shine green or visa versa. Don't tell students this at the beginning—let them figure this out. It is likely that on the first pass, some students will get the bulb to shine red and others will get the bulb to shine green. However, it is possible that they all connect them the same way and they all shine the same color. If this happens, be prepared to have one that you connect that shines the opposite color.

Keep the mystery of the bulbs going for students until they figure out that the direction the bulb is in the circuit matters. Once they observe both colors with their bulbs, say, *That's interesting! I wonder if the bulb has both colors and changing the way you connect the bulb in the circuit matters. What do you think?*

10. Forming Hypotheses

8 MIN

Materials: science notebook

Making sense of the results. Bring students back to the center circle and ask them to summarize what they discovered about these lightbulbs, how they work, and how this connects to their earlier work with the coil and battery.

Suggested prompts	Sample student responses
What did you discover about how these lightbulbs work?	*They only light up with 2 batteries not 1 battery.* *A single bulb can produce red light or green light depending on how it is hooked up in the circuit you make.* *When you flip something in the circuit (the two batteries together, the wires, or the bulb), the color of lightbulb changes from red to green or vice versa.*
Think back to our earlier work with the coil and the battery. What did we flip in that system?	*the orientation of the battery* *the orientation of the wire coil* *which ends of the wires were hooked to which ends of the battery*

Say, *This lightbulb appears to have the ability to detect flips in the system. This seems like it could provide us a useful way to try to resolve the two competing ideas we had earlier. Let's review these and add the idea that something could be flipping in part of the system too.* Review the ideas you recorded on the board before, updating B to replace the phrase "doing something else" with the phrase "flipping something in the system".

- We know the electric current is changing over time, and the rate of change is related to the rate of vibration.
- What we don't know is how its current is changing, but there are two possibilities:
  - A) The current is repeatedly switching from on to off (at a certain frequency).
  - B) The current is repeatedly flipping something in the system that causes the needle and speaker to move back and forth (at a certain frequency)

Form hypotheses. Say, *We could now turn these two possibilities into two competing hypotheses, and in those hypotheses we could also explain how we could use the LED in a circuit with the computer app to test both of them.* Show **slide P**. Give students the remaining time to work with their small group to discuss and record these alternate hypotheses.

Assessment Opportunity

This is an opportunity for you to assess students' ability to form hypotheses. They will develop two alternate hypotheses. Their hypotheses should be similar to the following:

- If the current from the computer is repeatedly switching from on to off (at a certain frequency), then when we hook the LED up to it, the LED will blink on and off and back again at a certain frequency but will remain the same color with each blink.
- If the current from the computer is repeatedly flipping something in the system, then when we hook the LED up to it the LED will blink from green to red and back again at a certain frequency.

11. Changing Frequency Demonstration with the LED

10 MIN

Materials: Day 2: Frequency investigations, science notebook

Carry out a whole-group interactive demonstration or investigation. Have students remain sitting in the circle around the demonstration table for this last investigation so they can all see the response of the LED.

Say, *You may have noticed that this small LED took more electric current to light up than the incandescent lightbulb did. That is one difference in how it responds to electric current.*

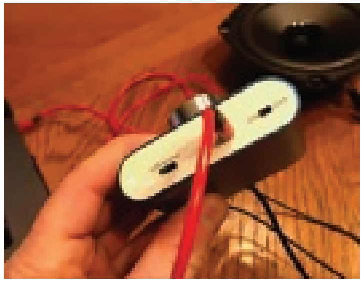
Additional Guidance

If students argue that this doesn't make sense because LEDs are supposed to more energy efficient and should therefore require less electric current, respond with the following: *LEDs are more energy efficient than older lightbulbs overall. This is because they don't produce as much heat as incandescent bulbs. More of the energy transferred to them by an electric current can be directly converted into light rather than converted into wasted heat. But the LEDs don't respond or light up when there is a really low current, while incandescents do.*

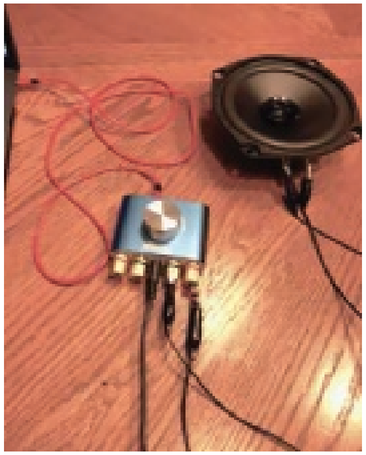
Say, *Because LEDs take a bit more energy to start lighting up, we are going to use a device called an amplifier to boost the amount of energy in the electric current coming from the computer. An amplifier is a device that helps boost the electric current without changing the pattern of change or frequency of change occurring in the current.*

Hold up the amplifier that you will be using. Ask students where else they have heard of amplifiers being used and what they do. Students will likely say they are used in music to make sounds louder. Remind students that we also used an amplifier in the Sound Waves Unit to do this. This will allow you emphasize that they make sounds louder without changing the pitch or frequency of those sounds.

Make sure the amplifier is plugged in. Hook up the amplifier to the computer using the male-male aux cord. Turn the switch on the amplifier to "on".

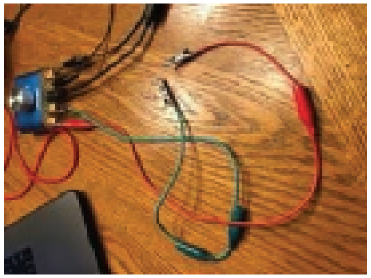


Connect the bigger speaker to two of the RCA jacks using two alligator clips.



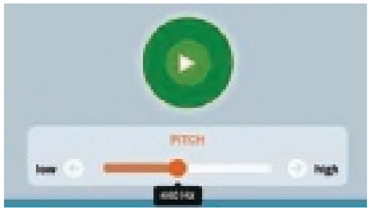
Say, *This bigger speaker has pieces in it that require more energy to move than the pieces that make up the smaller speaker. But likewise, they also provide louder sounds once we get them to produce a sound.*

Say, *This amp has two pairs of connections on it for two speakers. I've hooked up one pair of connections to one speaker. I am going to hook up the other pair to the LED. This way we can detect how both the speaker and the LED respond to changes in the electric current from the computer.*



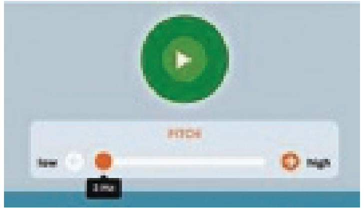
Connect the LED to the other RCA jacks using two more alligator clips.

Use the simulation that you used in the previous investigation and make sure it is paused right now. Set the frequency to 440 Hz. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)



Play the sound on the app, increase the volume on the computer to max, and then start slowly increasing the volume on the amp by turning the knob on the amplifier. Ask students what they observe as you do this. Students should say that it appears brighter. They will say that they notice that it is producing a different color (yellow) than it did in their small-group investigations.

Drop the frequency on the app to 10 Hz at maximum volume on the amp. Ask students what they notice both the light and the speaker doing. Students will say that the light appears to flicker and the speaker vibrates or moves back and forth. Some students will say the color of the lightbulb looks like it is changing.



Drop the frequency on the app to 4 Hz at the maximum volume on the amp. Ask students what they notice. Students will say that it is flickering between green and red. Invite students to come closer to inspect it. Note: To see it flicker at 3 Hz, you will have to detach the speaker.

Slowly increase the frequency, asking the students if they can still see it switching from green to red and back with each increase in the frequency. At some point (e.g., 30-60 Hz) students will say that it blurs together. Ask students how the blur of rapidly changing green and red might result in this new color it appears (yellow).

Tell students to use these observations to evaluate their two hypotheses. Ask students to circle the one that was supported by these results and cross out the one that was refuted by these results.

End of day 2

12. Navigation

10 MIN

Materials: science notebook, chart paper, markers

Share results of testing hypotheses. Display **slide Q**. Say, *In the last class you tested two competing hypotheses about what you would see from the LED when you connected it to the computer. Turn and talk with your elbow partner about which hypothesis was supported and which one was refuted. Be sure to cite evidence for your claims.*

Take stock in what we have figured out and what we still have questions about. Display **slide R** and make a two-column chart on the board similar to the one on the slide. Add the headings "What we figured out" and "Questions we have" to your chart. Lead a discussion to highlight what we have figured out and the questions that will motivate the reading. A sample dialog is shown below.

Suggested prompt	Sample student responses	Follow-up questions
What science ideas have we figured out using these lightbulbs and compasses?	*We figured out that the electricity coming out of the battery is different from the electricity coming out of the computer.*	*How is it different? What was your evidence?*
	We figured out that more energy or more electricity makes the lightbulb brighter.	*What was your evidence? What did the lightbulb do?* *How does the amount of energy affect sound?*
	We found that the light blinks (sometimes in different colors!) when connected to the sound generator in the computer.	*Do you know why this is happening?* *Do you know how the electric current is changing?*

Complete the T-chart. Finish this chart on the board with the class. Each student should also record the chart in their notebook. Your class's responses should be similar to those in the example shown below. After summarizing the "What we figured out" column together, pause and give students a couple of minutes to record their own questions in the second column in their T-chart in their notebooks. Tell students to draw a line under their questions to separate their list from questions they add from the class.

Assessment Opportunity

This is an additional place you can assess students' ability to ask questions to clarify gaps in their understanding about the flow of energy from a battery and a computer. Examples of what students might ask are

- questions about what is different about the current coming from the battery and current coming from the sound generator,
- questions about how the current is changing to make the LED shine red and then shine green,

*** Supporting Students in Engaging in Asking Questions and Defining Problems**

Students are asking questions of their own that arise from their careful observations of the behavior of a speaker and a lightbulb when connected to a battery and a computer. Some of what they observe may be unexpected, and they form these questions to seek additional information. Encourage students to ask questions that we can investigate in class or that we can use the resources we have available in our lab to find additional information to answer our questions. The additional information to answer our questions this time will come from the scientific reading in the next activity.

- questions about how the current from a sound generator is like the current coming from the battery when it is flipped, and
- questions about what is going on inside the computer that allows it to change the current over time in the first place.

Additional Guidance

The line separating the students' own questions from the class questions is to help the teacher see which ones came from that student vs. the ones they later copied from the whole-class chart.

Next, have students share their questions with the class. Instruct students to add the questions that other students share (that you are recording on the chart) in their own T-charts below the line they drew under their questions. Or you can have all students share 6-7 questions first, record these as a class, and then ask all students to add two to three of the most personally compelling or perplexing ones onto their own T-chart.

What we figured out

- The electric current coming from the battery is different from the electric current coming from the computer.
- Adding more batteries adds more energy to the system.
- The amount of current changes when we see brighter and dimmer light or louder or softer sounds.
- The current changes in a different way when we see a red light and a green light switching back and forth or when we see the light blinking on and off.
- To get both red and green light in the two-color LED with a battery, you have to flip the battery.

Questions we have*

- What is different about the current coming from a battery and current coming from the sound generator?
- How is the current changing to make the LED shine red and then shine green?
- How is the current from a sound generator like the current coming from the battery when it is flipped?

13. Reading: Music to My Ears

23 MIN

Materials: *Music to My Ears*, science notebook

Set up the students' need to know for the reading. Have students work with a partner through the reading.

Say, *We are going to investigate these questions by going to a reading. Scientists often go to expert sources of information to find out more about what they are investigating. You had questions after your investigations with the circuits, lightbulbs, and sound generator. Let's see if we can figure out the answers to our questions in the reading.*

Additional Guidance

Preread this passage and decide if your class should do this as a partner read—alternating paragraphs and reading aloud quietly in pairs. If you have enough time, have students read individually and stop to discuss questions with their partner. Try to adjust time so that this does not extend into an additional class period.

*** Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**
Students will be critically reading this scientific text that has been adapted for classroom use. Emphasize that scientists seek answers to their questions in multiple ways. We have answered many questions through investigations, and this

Leave the questions on the board and tell students to have their notebooks with the two-column chart visible while they read. Display **slide S** with the instructions for the reading. Allow students 20 minutes to complete the reading.* They will need their two-column charts for the reading.*

Perform active reading to learn more about our speaker system. We want to figure out the answers to the questions we have asked. Students will be reading in pairs. So students should read until they get to a question in bold, where they should pause until both students are to that point, quietly discuss their ideas about the question, and then continue reading. As they read, they should check off statements on their list of things they have figured out when they appear in the reading. This comes from the first column in their chart. They should put a star by new things they learn in the reading that will help them answer their questions in the second column of their chart. When both students have completed the reading, they should discuss the questions from their two-column chart that they have answered from the reading.

Assessment Opportunity

This is an opportunity for you to assess your students' abilities related to the NGSS SEP element: "Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s)" (p. 65). To assess this element, listen as students discuss their ideas with each other and as they offer their ideas in the class discussion that follows. Students will also use these ideas when they put the pieces together in the next lesson.

Additionally, this is the opportunity for you to assess your students' ability to use cause-and-effect relationships (a CCC) to explain the evidence they collected with the speaker and the lightbulbs. This opportunity goes beyond the crosscutting concept element that asks students to use these relationships to predict phenomena—students should be explaining phenomena in this lesson. Listen for your students using cause-and-effect relationships as they explain their ideas to their classmates or share them in the class discussion that follows. Students will also use these relationships as they put the pieces together in the next lesson.

A class checklist that you create for yourself can help you assess students' abilities to meet these scientific practices and crosscutting concepts. This checklist should not be for public display but used as a tool for recording your assessment. The checklist can include students' names and a column for recording how many times you heard or saw evidence of different elements. One element would be students adding a check mark to their two-column chart. Another would be students adding stars to the reading, and a third would be when you hear them discuss a cause-effect relationship from something they read with a partner. There is no minimum number of occurrences required for each of these that you should be looking for as you will get around to different groups at different times as you walk around the room. Here is an example chart you can make to record this:

	Analysis		Communication
name	✓ Identifies ideas we figured out before	☆ Identifies new science ideas	Discusses a cause-effect relationship
Student 1	/ / /	/ / /	y
Student 2	/	/	y

time, like scientists do, we will answer our questions through reading scientific text. Students should use the information in this text to obtain scientific and technical information that will help them explain patterns they have observed and the evidence they have collected about the speaker system. This information will help them to explain how the electric current flowing through the system connected to the computer is different from the electric current flowing through the system connected to a battery.

*** Supporting Students in Developing and Using Cause and Effect**

Students confirm several cause-and-effect relationships through a reading that they use to explain the changes in the electric current flowing through a circuit connected to a computer. They then explain how these changes in electric current change the vibrations in the speaker system to produce the many different sounds that we hear. Explaining the phenomena goes beyond prediction as the NGSS describes in this element of the CCCs. The cause-and-effect relationships that they either confirm or figure out in the reading and then use to develop explanations are as follows:

- The electric current from the sound generator is changing direction to flip the poles of the electromagnet.

Student 3	////	//	n
…...			

If you run out of time to survey this during class or want a more exact measure of student analysis of the reading, you can ask students to turn in their annotated reading *Music to My Ears* along with their notebooks at the end of the lesson to analyze them both.

- The frequency of these changes affects how fast the speaker vibrates and the pitch of the resulting sound.
- The amount of electric current changes also. This change affects the volume of the sound produced by the speaker.

Additional Guidance

Write the following hints on the board so students remember what to mark as they read:

- Check mark in reading = what we figured out from our list
- Star in reading = new science idea

Go over the instructions that appear at the beginning of the reading to ensure that students understand their task. Again, if you feel it best for your class of students, do this reading as a partner reading.

These instructions for the reading appear on *Music to My Ears*.

1\. Read silently until you get to a question in bold.

   a. Pause and wait for your partner.

   b. Quietly discuss your ideas to answer the question.

   c. Continue reading until the next bold question.

1\. As you read about them, place a check mark in the reading for things that we figured out from our two-column chart.

2\. As you read about new ideas to answer our questions, place a star by them in the reading.

3\. When you complete the reading, discuss the questions from your two-column chart with your partner.

   a. How would you answer the questions now?

Additional Guidance

Watching how students interact with their two-column chart as described in the steps above provides you an opportunity to assess how they are evaluating the information they are obtaining from the reading.

Listen in to the conversations students have with a partner during and after the reading. These provide you an opportunity to assess how they are communicating that information with a partner.

Materials: None

Lead a Building Understandings Discussion with the class. Display **slide T**. We have investigated several things in this lesson and read about the related science ideas. Lead a class discussion to help students synthesize and summarize these ideas. Use a dialog similar to that below. Be sure to insist that students support any claims with evidence from their investigations or the reading.*

Begin by saying, *We started this class with a two-column chart, listing the things we have figured out. Take a minute to review those and we will add to the list based on your reading. Also, think individually about what you want to add to the list and do so in your notebook.*

Give students a minute or two to read over the list and think of what they can add based on the reading. After a minute or two, begin the discussion.*

Suggested prompt	Sample student responses	Follow-up questions
Can someone share one new thing you learned from your reading that will help us answer our questions?	*We figured out what was different about the electric current that comes from a computer compared to the current that comes from a battery.*	*How is the current different?* *What is your evidence?*
	We figured out that the electric current is changing direction when you either flip the battery or use the computer.	*Where did you learn that? What is your evidence?* *How does that help us answer our questions?* *What do these changes mean for the speaker and the sound we hear?*
	We figured out that the changing electric current is what makes all the different sounds that we hear.	*What are all the ways the electric current is changing?* *Does anyone have evidence to support _______'s claim?*

* Strategies for This Building Understandings Discussion

A Building Understandings Discussion is a useful kind of discussion following an investigation because the purpose is to focus students on drawing conclusions based on evidence. Your role during the discussion is to invite students to share conclusions and claims and to push them to support their conclusions and claims with evidence. Students can disagree with one another and the class does not need to reach consensus on all ideas shared, but rather, areas of disagreement can motivate future investigations. Helpful prompts during these kinds of discussions include the following:

- What can we conclude?
- How did you arrive at that conclusion?
- What's your evidence?
- Does any group have evidence to support Group A's claim?
- What data do we have that challenges Group B's claim?

Key Ideas

Purpose of this discussion: The purpose of this discussion is to summarize and synthesize ideas that students have figured out in Lesson 8 investigations and reading. Students started a list of what they have figured out at the beginning of day 3 and will now add to the list. Some of the ideas listed below are ones that likely came up and are on the list from the beginning of day 3. The key science ideas from Lesson 8 are as follows:

- More batteries in the circuit gives more current.
- More current produces brighter light and louder sounds.

- More current means more energy is transferred.
- The more energy that is transferred, the stronger the forces are in the magnetic field.
- Electric current changes direction when you flip the battery in a circuit.
- Electric current from a computer changes direction.
- Frequency tells us how many times per second that the direction changes. (previous idea from Sound Waves Unit)
- The frequency determines the pitch of sound. (previous idea from Sound Waves Unit)
- Current that flips direction causes the poles of the electromagnet to flip.
- When the poles flip, the direction of forces (attractive vs. repulsive) flips in the field produced by the electromagnet.

Listen for these ideas:

- Students should connect energy and forces. They should realize that when there is more energy transferred, there are larger forces.
- Students should realize that this energy transfer and the forces that occur are between objects that are not touching.

15. Navigation

2 MIN

Materials: *What is electric current?* (optional)

Motivate the lesson that follows. Say, *We have figured out a lot! We figured out how energy is transferred between magnets in Lesson 7. In Lesson 8, we figured out that the electric current is different coming from a computer than the current coming from a battery. The electric current from a computer changes in direction and amount to make all the sounds we hear from a speaker. Next time, let's see if we can put some of our ideas together about energy to update our models to explain our speaker system.* Collect student notebooks to review before the next lesson.

Additional Guidance

Electricity extension opportunity. Lessons 8-12 include guidance on how to provide a coherent enrichment experience for students who are interested in learning more about electricity or who have met and exceeded the performance expectations. These might also be helpful if your state has standards in addition to those laid out in the NGSS related to electricity and circuits. Look for guidance with the heading "Electricity extension opportunity" to find optional enrichment support over the next four lessons. There may also be optional handouts associated with this enrichment. For more details on these opportunities, see *Electricity extension opportunity*.

In this lesson, students learn about the role of electric current in producing an electromagnet that can switch polarity. Students do not learn what *electric current* is. For students who want to learn more, *What is electric current?* offers an extension opportunity that you can assign as home learning. In this handout, students learn that electric current is the movement of charged particles called *electrons*. They also learn that electrons can move very slowly in the wire, much more slowly than electrical energy is transferring. Students are directed to a PhET interactive where they can apply ideas to build a circuit that powers a lightbulb. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

LESSON 9

How do the magnet and the electromagnet work together to move the speaker?

Previous Lesson

We asked questions about the energy flow coming from a computer and a sound generator vs. the energy flow coming from a battery. We varied the volume and frequency of sounds being produced and observed the effects on a speaker, a lightbulb, and a wire coil. We gathered information on how changes in the electric current (the cause) result in changes to a magnetic field (the effect) within the speaker system.

This Lesson

Putting Pieces Together

3 DAYS

We are ready to start putting the pieces together to explain the speaker. We add to our list the cause-and-effect relationships that we figured out in Lessons 7 and 8. Then we construct a classroom consensus model to explain these relationships and how they work together to produce the patterns of movement we see in the speaker. We brainstorm and read about other applications for this technology and notice that there are some electromagnets that can move very big things, like trains and cars. This is weird because our electromagnets are very weak. We wonder what we could do to make magnetic forces strong enough to lift trains and cars.

Next Lesson

We are wondering about how magnets can be strong enough to lift a train, so we will co-design an investigation using a digital scale to test the relationship between distance and magnetic force. Our data will provide more evidence that as distance between magnets and between magnets and test objects increases, the magnetic force decreases.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Revise a model to describe how changes in a magnetic field due to changing electric current explain cause and effect relationships between parts of a speaker system (magnet and coil of wire).

Ask questions about how changing the speaker system (cause) could affect the strength of the forces in the magnetic field (effect).

What Students Will Figure Out

- Changing the current in the electromagnet changes the poles of the electromagnet so that sometimes the pole facing the magnet matches (N-N or S-S), and sometimes it does not (N-S), which changes the shape of the magnetic field.

- Thus changing the current will alternately produce force pairs between the magnet and the coil of wire that push them apart (repulsive force) and pull them together (attractive force).
- When the direction of the forces changes, the coil (and the attached speaker cone) will move back and forth (vibrate).
- Energy is transferred into the magnetic field by the electric current flowing through the electromagnet and stored until it is converted into kinetic energy in the coil and speaker cone and then transfers out of the system as sound energy.

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Review what we have figured out in prior lessons.	A-B	
2	20 min	**TRACING CAUSE-EFFECT RELATIONSHIPS** Students work in groups to come up with a list of cause-effect relationships that we have uncovered in the first lesson set. The class then records a consensus list of the relationships we think are most important for understanding how the speaker works.	C-D	*Lesson 9: Cause-Effect Table*, Cause-Effect Tracker poster (created in Lesson 6), chart paper, markers, blank Cause-Effect Tracker table (created for this lesson), Magnets (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), sticky notes
3	15 min	**MAKE MODELS IN GROUPS** Students convene in small groups to refine a model for explaining how the speaker works.	E	chart paper, colored pencils, markers, arrow-shaped stickies (optional)
4	2 min	**NAVIGATION AND HOME LEARNING** Assign home learning in preparation for an activity we will do together on the following day.	F	
				End of day 1
5	30 min	**BUILD A CONSENSUS MODEL IN A SCIENTISTS CIRCLE** The class collaborates on a consensus model for the speaker.	G-K	*Lesson 9: Cause-Effect Table*, chart paper, colored markers, colored pencils, sticky notes
6	15 min	**SHARE RESEARCH FROM THE HOME LEARNING** Students share what they found out from their home learning in order to begin a conversation about related phenomena and motivate the reading jigsaw.	L-M	
				End of day 2
7	20 min	**JIGSAW READING ABOUT BIG MAGNETS** Students become experts in one of three readings focused on magnets moving big things and then discuss in small, mixed-expertise groups.	M-P	*Magnetic Levitation Trains*, or *Junkyard Magnets*, or *Electric Motors*

8	25 min	**REVISE AND ADD QUESTIONS TO THE DQB** Students collect, revise, and add questions about the strength of forces.	Q-S	sticky notes, DQB (or a fresh piece of chart paper)
				End of day 3
		SCIENCE LITERACY ROUTINE		Student Reader Collection 4: *Noncontact Energy Transfer*

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Lesson 9: Cause-Effect Table* • *Magnetic Levitation Trains* or *Junkyard Magnets* or *Electric Motors*	• chart paper • colored pencils • markers • arrow-shaped stickies (optional) • sticky notes	• Cause-Effect Tracker poster (created in Lesson 6) • chart paper • markers • blank Cause-Effect Tracker table (created for this lesson) • Magnets (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • sticky notes • colored markers • colored pencils • DQB (or a fresh piece of chart paper)

Materials preparation (45 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare chart paper for posters.

- For the Cause-Effect Tracker poster, write the title at the top of a piece of chart paper and then sketch a table with three columns. Label the columns "Change to the system (cause)," "Effect on the system," and "How or why." Add sticky notes to remind students of the sentence frames we have been using to describe cause-effect relationships. To the left of the table, put a note that reads "When we …" On the line between the first and second columns, put a note that reads "we will observe". On the line between the last two columns of the table, place a note that reads "because." This will be posted below the Cause-Effect Tracker poster created in Lesson 6.
- Title the Classroom Consensus Model poster.

Test the Lesson 9 version of the computer interactive on the computers that students will be using. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students put together ideas from Lessons 7 and 8 about electric current to build a model for the speaker. They make connections among forces, energy, and magnetic fields. While they have been using forces and energy in previous units (e.g., 8.1 Broken Things and 8.2 Sound), this is the first explicit opportunity they have to think about how forces, energy, and magnetic fields relate to one another. Students put the pieces together that forces transfer energy and that the energy stored between the magnets is dependent (to some degree) on the arrangement of the magnets in the field (i.e., their distance from each other). In the next lesson set (Lessons 10-12) students add to this understanding because they have been thinking about factors that determine the strength of magnetic forces. They realize that the energy stored in the field is probably dependent both on the arrangement of the magnets <u>and</u> on the strength of the magnetic forces, which is determined by factors like the size of the magnets (for both permanent and electromagnets) or the electric current amount (for electromagnets).

Where We Are NOT Going

Students are not expected to be able to relate energy and force in a quantitative way. The energy stored in the field of two magnets with a certain arrangement is determined by the work that would have to be done in order to bring those magnets to that arrangement. That work is going to be the integral of the forces over the distance the magnets travel. This is a university-level understanding of the relationship between forces and energy. We do not define energy in terms of work, but rather explain that forces transfer energy.

1. Navigation

8 MIN

Materials: science notebook

Take stock of what we know about the speaker. Have students open their science notebooks to the page where they have their consensus models from Lesson 6. Discuss the focus of our investigations over the course of Lessons 7 and 8.

Suggested prompts	Sample student responses
When we decided to investigate the magnets on the carts, what were we trying to explain?	*energy transfer in the system and how the distance between the magnets affects it*
When we decided to investigate the electromagnet and the music player in this set, what were we trying to explain?	*We wanted to know how the forces were pushing and pulling even though nothing was flipping around inside the speaker.* *We wanted to know what the music player was doing and what was coming out of it and if it was the same thing that was in the battery.* *We wanted to know about where the energy was coming from that went into the magnetic field.*
What were some of the surprising things we figured out when we started to investigate the electromagnet and the music player?	*that electric current was flowing from the music player, and it could turn on lightbulbs just like the battery* *that the electric current coming from the music player is changing and that can make the magnetic field change just like physically flipping around the magnets*

Discuss the connection between energy and forces. Project **slide A** and ask, *So what can we say about energy and forces in a magnetic field? What determines how much energy is stored in the field? Turn to a partner and discuss these questions.* Have students discuss as a Turn and Talk. Then say, *Let's come back to this question again later in the lesson and see if we can make the connection among forces, energy, and the magnetic field.*

Introduce the lesson question. Present **slide B** and introduce students to the question, "How do the magnet and the electromagnet work together to move the speaker?"

Say, *When we started investigating the electromagnet, we wanted to know how the magnets in the speaker work when they do not touch. We've done some mapping of this space and have learned that it's called a magnetic field, and the field determines the direction of the force between the two objects. Today we will put the pieces together and try to use what we figured out about magnetic fields to explain how the magnet and the coil of wire exert forces on each other without touching.*

2. Tracing Cause-Effect Relationships

20 MIN

Materials: science notebook, *Lesson 9: Cause-Effect Table*, Cause-Effect Tracker poster (created in Lesson 6), chart paper, markers, blank Cause-Effect Tracker table (created for this lesson), sticky notes, Lesson 9 Magnets (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Use a cause-effect table to document what we know. Display **slide C**. Say, *In Lesson 6, we made a list of some cause-effect relationships that we thought were important. I think we may have some new cause-effect relationships now that we have done some more investigations. Take a moment to look back in your notebook for ideas. Look for specific changes that we made to the system in Lessons 7 and 8 and the effects that we observed when we made those changes*. Hand out *Lesson 9: Cause-Effect Table*. Instruct students to begin filling out the tables in the handout in small groups.

As students work, make sure the Cause-Effect Tracker poster that the class created in Lesson 6 is posted at the front of the room. Next to (or beneath) that Cause-Effect Tracker poster, post the blank Cause-Effect Tracker table that you prepared for this lesson so that it looks like we are adding onto that list. After 8 minutes, solicit student ideas about changes that we made to the system. If students are stumped, consider scaffolding their brainstorming by going lesson by lesson, as in the prompts below.

Suggested prompts	Sample student responses	Follow-up questions
What changes did we make to the system in Lesson 7 when we were working with the cart, the bumper, and two permanent magnets?	*We changed the distance between two magnets.*	*What were the different ways that we changed the distance? (Look for students to suggest closer for repulsive and further for attractive.)* *What was the effect on the system for each orientation, and how or why did those changes cause those effects? (Record these as two, separate cause-effect relationships.)*
What changes did we make to the system in Lesson 8?	*We connected the music player to a lightbulb.* *We connected the coil to the music player instead of the battery.* *We switched the poles of the battery that the wire is connected to.*	*What was the effect of the change on the system and how or why did that change cause that effect? (Record this in the table.)*

Make a public record of our ideas. As students share their ideas, ask, *Did anyone else record this relationship?* If another group (or groups) volunteers "yes", ask them to share with the class what they wrote. Then either rephrase the relationship to capture the most important pieces from each version or ask, *Can someone summarize what these groups are saying?*

Record student ideas on the Cause-Effect Tracker poster at the front of the room. As students share, ask, *Which lesson did you make that observation in?* Record the lesson number in the table, as shown below. If students are not sure about a how or why relationship, ask the class to brainstorm ideas. Highlight how or why relationships that we still have questions about.

	Change to the system (cause)		Effect on the system		How or why
When we	L7: bring the magnets closer together when the forces are repulsive	**we observe**	that they will move back apart	**because**	energy stored in the magnetic field transfers into the motion of the magnets. (KE)
When we	L7: bring the magnets further apart when the forces are attractive	**we observe**	that they will move back together	**because**	energy stored in the magnetic field transfers into the motion of the magnets. (KE)
When we	L8: connect the music player to a lightbulb instead of a coil	**we observe**	L8: the lightbulb brightness changes with the volume and pitch (frequency) of music	**because**	there is an electric current coming out of the music player that is changing all the time (direction and strength), whereas the battery only had one kind of current (strength and direction didn't change).
When we	L8: switched the poles of the battery	**we observe**	L8: the lightbulb turned from red to green and back (alternating with the direction of the current) the poles of the electromagnet (N and S) switched	**because**	
When we	L8: connect the coil to the music player instead of the battery	**we observe**	the speaker vibrates or moves back and forth	**because**	there is an electric current coming out of the music player that is changing all the time (direction and strength), and that changes the shape of the magnetic field around the electromagnet or permanent magnet.

Use the interactive to check our understanding of cause and effect and the magnetic field. Say, *We are going to be modeling these cause-effect relationships at the end of this lesson and will make another consensus model. What did we do in the past to see what the magnetic field would actually look like when we made changes to the field?*

Look for students to recall the interactive. Then bring up the Lesson 9 version of the interactive at the front of the room. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Ask students for suggestions of which cause-effect relationships we can try out on the interactive. You may want to add any new relationships that students suggest to the cause-effect tracker before moving on.

Highlight the observation that changing the direction of the current in the wire will change the directions of the forces in the magnetic field. This is the key idea to be reinforced by the interactive. Remind students that the pointers we see in the interactive represent the direction that a compass needle would point if we put it at that place in the field.

Add to our how or why explanations from the first lesson set. Say, *We were unsure about how to explain some of the cause-effect relationships that we identified in Lesson 7. Let's go back and see if we can write some better explanations for these relationships now that we have taken this energy perspective. Spend a couple of minutes talking about this in your groups and then we can go back to our class chart and record our ideas.*

After 5 minutes, solicit student ideas. Use a different colored marker to add to the table you made in Lesson 6. If there is not enough room, consider using sticky notes to expand the last column of the table. Look for students to use energy transfer and changing current to expand on the explanations the class developed in Lesson 6.

Identify important relationships to include in the consensus model. Once the table is complete, display **slide D**. Ask students to turn and talk about the question on the slide: Which of these cause-and-effect relationships do we need to explain how the speaker makes sound? Remind students that this can be any of the cause-and-effect relationships on the poster, not just the ones we came up with today. Say, *In Lesson 6, we used these relationships to explain interactions we observed between the permanent magnet and the electromagnet, isolated from the speaker system. Now it is time to come back to the speaker system to apply our ideas.*

After a couple of moments, ask students to nominate some important cause-effect relationships and explain why they think they will be important. Highlight or underline the relationships (or parts of a relationship) that students nominate, using a different color than the one you used in Lesson 6. If students suggest a relationship other than those listed, use probing questions to isolate what is important for explaining the speaker. For example, if students suggest that when we sprinkle iron filings around a magnet we see a pattern in the way they line up, ask, *What is important here, the cause and effect of what happens to the test objects or the magnetic field that the cause-effect relationship revealed to us?* Invite other students to weigh in on any newly nominated relationship to be sure it represents the shared thinking of the entire class. The goal is to isolate the relationships and parts that students should include in the consensus model.

3. Make models in groups. 15 MIN

Materials: science notebook, chart paper, colored pencils, markers, arrow-shaped stickies (optional)

Independent thinking in student notebooks. Remind students that the purpose of building individual models is to gather their initial thinking. They will have a chance to share their individual ideas in small groups, and then the whole class will discuss how to put these pieces together. Tell students, *We want to capture in our model what we figured* *out in Lessons 7 and 8. What will we need to change or add to the model we developed in Lesson 6 in order to do that*? Give students at least 3 minutes to record some of their initial ideas in their notebooks.

Additional Guidance

You can scaffold this activity to highlight new additions to the model by taking a photo of the Lesson 6 consensus model and printing copies for students. During this individual time, ask students to attach the photo to their notebooks and sketch out their ideas on top of the model using a dark pen.

Work in small groups to revise a model. Form small groups with no more than four students. Give groups 10-12 minutes to work on revising their Lesson 6 models to show how the speaker works (use **slide E** to orient students to the task). Have students revise their Lesson 6 models in their notebooks rather than using a poster. Suggest that students use different colors and/or labels to indicate which parts of the model are new. They can use the same arrow-shaped stickies that they used in Lesson 6 and move them onto their new models, or you can provide them with new stickies.

Assessment Opportunity

As you move around the classroom, ask students to compare their new model to the one they made in Lesson 6. Look for students to point out one or more of the following similarities: (1) both systems have a permanent magnet and an electromagnet, (2) both systems have forces that act at a distance, (3) both systems can be explained by forces acting in a magnetic field (and/or energy transferring in a magnetic field), and (4) both systems have electric current flowing through the wire going to and from the electromagnet. Look for students to point out the following differences: (1) the speaker has a music player, not a battery, as the source of the electric current, (2) the speaker has a cone that vibrates, and (3) the forces and magnetic fields in the speaker are constantly changing due to the changing current from the music player.

4. Navigation and Home Learning

2 MIN

Materials: science notebook

Assign home learning. Display **slide F**. Say, *We have figured out a lot about permanent magnets and electromagnets in the past couple of weeks. Let's see how far we can apply this model to explain other systems in the world beyond the ones we've investigated so far in class. I bet there are even more magnets in our world than those we saw when we brought our compasses home in Lesson 4. Let's do a little research and find out more about what other designed systems are in our world that we might now be able to explain. Where else do we see magnets being used to make things move? You can do one or any combination of the following to answer this question:*

- *Ask your family and community members if they know of something that uses permanent magnets and/or electromagnets to make things move.**
- *With a friend or family member, use a computer or phone to search the internet for different uses of permanent magnets and/or electromagnets to make things move.*
- *Check the library for books or articles about permanent magnets and/or electromagnets that make things move. Ask a librarian for support!*

*** Attending to Equity**
Framing students' families and communities as legitimate funds of knowledge can serve multiple purposes. It can (1) help students feel like they belong in the science classroom by situating their family and community knowledge as productive resources for science, (2) engage students' families in conversations about what is happening in the classroom, and (3) help students make connections between the science classroom and their everyday lives.

Collect student notebooks to review their models before students leave class.

Assessment Opportunity

Collect student notebooks at the end of day 1. Before day 2 of this lesson, review the models students drew in their notebooks. Use *Rubric for Model in Lesson 9* to structure your feedback. Note that this particular rubric is not designed for students to use or see before you provide feedback on it for them. Students will get time on day 2 of this lesson to review this feedback before moving into consensus building.

End of day 1

5. Build a consensus model in a Scientists Circle.

30 MIN

Materials: science notebook, *Lesson 9: Cause-Effect Table*, chart paper, colored markers, colored pencils, sticky notes

Remind students about home learning. Say, *I hope you had a chance to do some research about other applications for magnets. We will use what you figured out from your research later in our lesson today. Before we do, let's come to some consensus on the model work we were doing last time.*

Return feedback on models. Before beginning the Consensus Discussion, give students a couple of minutes to process the feedback on their models individually.

Form a Scientists Circle for a Consensus Discussion. Ask students to bring their science notebooks. The purpose of this discussion is to put the pieces together about what we've figured out about magnetic fields to revise the classroom consensus model for explaining the at-a-distance forces in the speaker.

Prepare the Progress Tracker. Use **slide G** to orient students to this task. In their notebooks, students should find a new two-page spread in their Progress Tracker section. Have students draw a three-box Progress Tracker to help the class come to an agreement about the evidence and what the class has figured out in words and pictures. First have students write down the question they have been trying to answer: *How do the magnet and the electromagnet work together to move the speaker?*

Ask students what evidence they have been working with to answer this question (e.g., carts, computer interactives, experiments with LEDs). Tell students that our consensus model might fit on one page or it may span several pages, and that is fine.

Facilitate a Consensus Discussion. Display **slide H**. Ask three students to offer proposals for what should go in the model. Let each student explain the modifications they made to the Lesson 6 model. Then ask volunteers from the Scientists Circle to support or challenge these proposals based on evidence and to suggest modifications. During the discussion, ask students how to represent their ideas visually. To record an agreed-upon idea, use a different color marker to modify the Lesson 6 model.

Prompts for eliciting student proposals for what should go in the model

- *What new parts do we need to include?*
- *What parts from the old model do we not need anymore?*

*** Strategies for This Consensus Discussion**

If your students have used materials before, consider asking for 2-3 volunteers to facilitate this Consensus Discussion while you observe (or even participate as a student) and add to the model. Give these volunteers *Guidance for Student Facilitators* to guide their facilitation. These students will take on the role of prompting other students to share what needs to be in the model, pushing them for evidence they have to support their ideas, and encouraging them to share ideas about how to represent it. Suggested prompts below are also included in *Guidance for Student Facilitators* to help elicit, probe, and challenge student ideas to help them come to consensus during this discussion. Note that this may add an additional 10-15 minutes to class time.

- *How should we represent both cause and effect for each of these relationships?*
- *What additional versions of the system do we need to include in order to capture each cause-effect relationship?*

Prompts to ask students to support or challenge proposals

- *What ideas are we in agreement about?*
- *Are there still places where we disagree? Can we clarify these?*
- *Are there still areas of controversy, confusion, or discontent?*
- *Who feels like your idea is not quite represented here?*

Prompts for proposing modifications or coming to consensus with conflicting ideas

- *How are these explanations similar? How are they different?*
- *How could we modify what we have so that we account for the evidence we agree is important to consider?*
- *Is there more evidence or clarification needed before we can come to consensus? What is that?*

Come back to the connection among energy, forces, and the magnetic field. Display **slide I**. Pose the questions on the slide to the class. You may want to give students another chance to turn and talk.

- How are forces related to energy in the magnetic field?
- What determines how much energy is stored in the magnetic field?

Lead a short discussion to make connections between energy and forces. Revoice and record the following student ideas on chart paper if you hear them:

- Forces transfer energy.
- Energy is related to movement.
- Energy transfers in and out of magnetic fields.
- Energy is stored in magnetic fields.
- The amount of energy depends on the strength of forces.
- The amount of energy depends on the arrangement of the magnets (distance, orientation).

Say, *We have a lot of ideas. It sounds like we are on the right track. Let's take a look at two statements that put all these ideas together and see if they make sense to us.* Display **slide J**. Give students a moment to look at the statements on the slide. Then ask, *Do these statements reflect our ideas?* Solicit student responses. Push students to make connections among the ideas on chart paper, the statements on the slide, and the classroom consensus model:

- Forces transfer energy into the magnetic field, and forces transfer energy out of the magnetic field.
- The amount of energy that is transferred into and stored in the field is dependent on the arrangement of the magnets in the field.

Say, *So when I bring two magnets together, the amount of energy stored in the field is going to depend on the magnetic forces and the arrangement of the magnets.*

Remind students that energy does not disappear. Ask, *Where does the energy go once it leaves the speaker? We may need to think back to the Sound Unit.* Look for students to suggest that the energy goes into making sound or it ends up in the air. Some students may point out that it ends up as heat (kinetic energy of particles in the air). Accept only a couple of student ideas to reinforce the idea that energy goes someplace. Do not worry about the details here; the goal is to remind students that energy does not disappear once it leaves the system and that we followed the flow of energy from the speaker in 8.2 Sound.

Have students record the classroom consensus model in their science notebooks. Students should record the final representation in the Progress Tracker section of their science notebooks as a 3-box consensus model. The model should incorporate the cause-effect relationships articulated by the class. You can annotate these relationships on the model or consider using a numerical or alphabetic labeling system to align the relationships on the Cause-Effect Tracker poster to the relationships in the consensus model.

Key Ideas

Purpose of the model: The purpose of this Consensus Discussion is to build a common, class-level model to explain how magnetic forces cause vibration in the speaker, drawing on all the ideas learned in Lessons 1–8.

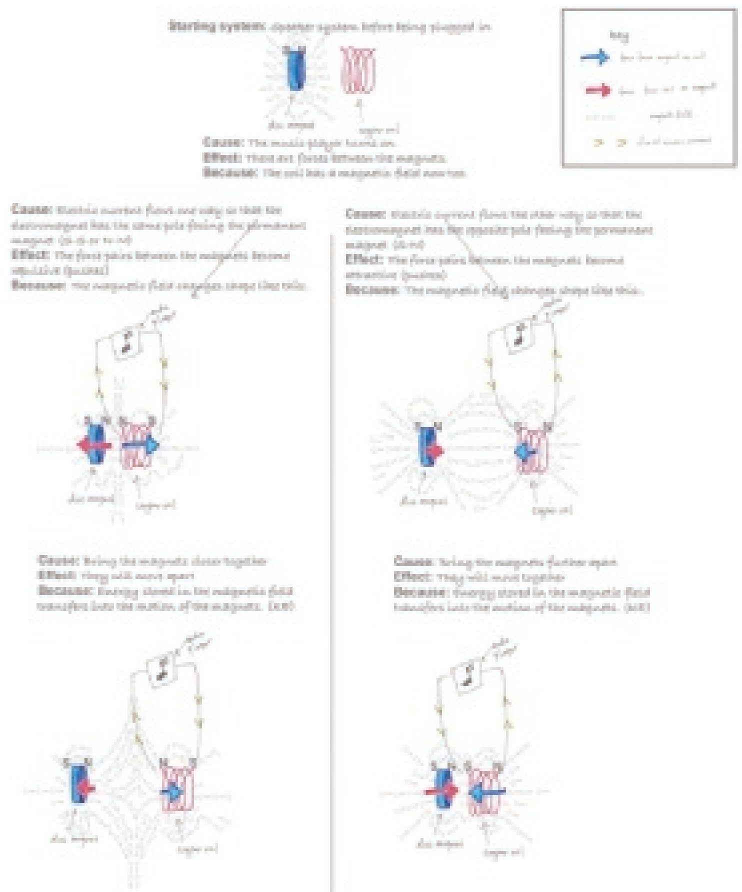
The model should include these Key Ideas:

- The coil of wire with a current has a magnetic field around it similar to the permanent magnet. The coil of wire is a magnet (electromagnet). (from Lesson 6 consensus model)
- There is an invisible space around the magnet and the electromagnet, and there is a direction to this space that changes when you change the poles. This space is called a magnetic field. (from Lesson 6 consensus model)
- Forces transfer energy out of an invisible magnetic field into the rest of the system, producing the changes in motion we observe between a magnet and an electromagnet. (Encourage students to articulate this interaction without representing energy as a "thing" in the model.)

Additional Guidance

In a speaker, the voice coil sits nested inside the permanent magnet but not touching. If the magnet and voice coil touched, this back-and-forth movement would wear down the voice coil, causing the speaker to not function. Thus, having a small distance between the voice coil and the magnet is essential for a properly functioning speaker. Magnetic fields around the two magnets (the permanent magnet and the voice coil) make this movement possible without contact.

Keep the classroom consensus model in a public space. Your representation will look something like the image below, though representations can vary.

Question	Source of evidence
How do the magnet and the electromagnet work together to move the speaker?	Carts investigation Electric circuit investigations
What we figured out in words and pictures	
	

Remain in the Scientists Circle to take stock of questions we've answered. Display **slide K**. Have students take another look at the Driving Question Board (DQB). For answered questions, on the same card as the question, have students record an answer they think they have. Then have students move the answered questions to a different section of the DQB (labeled "Questions we have answered").

6. Share research from the home learning. 15 MIN

Materials: None

Broaden to related phenomena by sharing home learning. Display **slide L**. Say, *Wow, we have answered so many of our questions about the speaker! It really feels like we understand how this system works. What about some of the other things we think use permanent magnets and electromagnets? Can we explain those systems too? Let's spend some time sharing our research with others and looking for common ideas.*

Scaffold students in summarizing some new ideas from the home learning by facilitating short conversations with two other students. Say, *Turn to a partner. I will set a timer for three minutes. When I say so, share with your partner what you figured out from your research at home. Look for one common idea that you both figured out. This can be an application, like, we both thought of the same thing, or it could be something else, like we both thought of different things, but they both used electromagnets to make something vibrate. Then come up with one additional thing that your partner figured out that you did not. Record both ideas in your notebook.*

Set a timer for three minutes. When the timer goes off, tell students to do the same thing with someone on the opposite side of the Scientists Circle. Say, *Make eye contact with someone on the opposite side of the circle. I will set the timer for another three minutes. When I say so, stand up and meet with the person that you made eye contact with. Again, you will share what you figured out from your research at home. Look for one common idea that you both figured out and one additional thing that your partner figured out that you did not. Record both ideas in your notebook.*

Help students find their seats again. Then say, *Who wants to share an application or theme that surprised you? This can be from your own research or something that you learned from a peer.*

Look for students to suggest diverse applications such as these:

- sprinklers
- junkyard magnets
- particle colliders (e.g., the Large Hadron Collider)
- maglev trains
- pinball machines
- electric motors

Navigate to the readings by focusing on three applications where magnets move big things. Display **slide M**. Say, *Our research revealed a lot of applications for this technology. I thought it was interesting that some of the applications we shared were making something very small move, like in the speaker, but some of them were making something very big move. Here are some examples of electromagnets that move very big things. Does anybody recognize these pictures from their research?* If a student researched one of the applications on the slide, ask that student to explain what we are looking at. Fill in the gaps and revoice students' ideas until all the photos on the slide have been talked about.

Say, *Let's come back to these big magnets next time. May we can divide and conquer to dig a little bit more into how we get magnets that are this big.*

End of day 2

7. Jigsaw Reading About Big Magnets

20 MIN

Materials: *Magnetic Levitation Trains*, or *Junkyard Magnets*, or *Electric Motors*, science notebook

Use the jigsaw strategy for three readings about other applications for electromagnets. Display **slide M**. Remind students that last time we had some questions about very big applications of magnets. Say, *I have a couple of readings that we can use to find out more about these big electromagnets*. The readings can be found in the student materials, or as handouts. Guide students in doing a close reading in expert groups of 4-6. In a class of thirty, you will need to have two expert groups for each topic. The purposes of these readings are to

1. strengthen and reveal connections to other magnet-related phenomena that students have experienced and
2. re-anchor the unit by providing a new set of contexts for students to ask questions about in which the strength of magnetic forces is foregrounded.

Students should use the following close-reading protocol, also on **slide N** and in the *Student Procedures*.

Before	1. Record the name of your group's reading at the top of your group's poster.
	2. **With your group**: Identify the question(s) you are trying to answer. Record them in your notebook for later.
During	3. Read once **individually** for understanding to see what the reading is about.
	4. Read a second time out loud **with your group** to highlight a few Key Ideas.
After	5. Summarize the Key Ideas in your notebook. Make sure to include • a description and/or diagram of how the device works that your group read about, • why it is important that the device relies on an electromagnet, and • at least one key similarity and one key difference between your device and the speaker that your group noticed.

Students discuss in mixed-expertise groups. Display **slide O** and explain to students that they will move into new groups of three. Each group of three will have a student expert for each reading. One way to get students into these groups is to ask students to stand in three lines: a line of experts on reading 1, a line of experts on reading 2, and a line of experts on reading 3. Then ask the first student in each line to make the first group of three, the second student in each line to make the second group, and so forth.

Display **slide P**. Read through the directions on the slide and field any questions students have about the logistics of the task. Each round should take about three minutes. For the first two rounds, set a one-minute timer three times in succession to help students organize their time. For the last round, you don't need to set a timer. Walk around the classroom to make sure that students have had sufficient time to discuss the question and then bring the class back together.

Small-Group Talking Stick - Round 1

- Pass around a pencil as a "talking stick" to take turns having each person share their device and what it does (one minute per person).
- As each person shares, think about (1) an important similarity between your devices and (2) an important difference between your devices, but don't add your own ideas yet.

Small-Group Talking Stick - Round 2

- Pass the talking stick around again to have each person share one similarity they noticed among all three devices and one difference they noticed (one minute per person).

Small-Group Open Discussion - Round 3

- With your group, brainstorm what we would need to change about the electromagnets in our classroom for them to work in this new application, and why.

8. Revise and add questions to DQB. 25 MIN

Materials: sticky notes, DQB (or a fresh piece of chart paper)

Collect questions about the strength of forces. Say, *We read about magnets that can lift entire trains and make them move hundreds of miles per hour. We read about magnets that can make cars go zero to sixty in less than 2 seconds. We read about magnets that can pick up cars, trucks, and tons of junkyard scrap effortlessly and then drop it somewhere else. How do people build magnets that can apply forces strong enough to do all those things? Our little electromagnets from our homemade speakers could barely move a paper clip, let alone lift up a passenger train!*

Display **slide Q** and say, *What would we need to do to make an electromagnet strong enough to move cars and trains?* Elicit several student ideas. Highlight student ideas about stronger forces or more force.

Display **slide R**. Say, *It sounds like a lot of our ideas are about increasing the strength of the forces in the magnetic field. I think we may have asked some questions about making magnetic forces stronger on our DQB. Let's go back to the DQB and see if we can find some of those questions.* You can use a round robin structure to facilitate this process. Ask one student to come up and find a question and then sit back down. Then the next student in the circle comes up until students can no longer find questions related to the strength of forces.

Revise and add questions in small groups. Display **slide S**. Distribute sticky notes evenly among the groups. Tell each group that they should spend this time revising an existing question or coming up with a brand new one. Remind students to use the cause-effect language on the slide to make it clear what relationship we need to investigate in order to answer the question:

When we *change to system* will we observe *effect on system* ?

Once groups have each come up with at least one question to put on the DQB, arrange these questions in a new section of the DQB or on a new piece of chart paper under the heading: "Questions about the strength of forces in a magnetic field". You might also consider posting these questions on the Related Phenomena poster that was created in Lesson 1. Students will return to these questions in Lessons 10 and 11.

Motivate the next lesson. Say, *Wow, we have some really interesting and concise new questions. Let's come back next time and choose one of these to investigate together. Then, maybe we can divide and conquer in order to answer the rest.*

Additional Guidance

Electricity extension opportunity

Lessons 8-12 include a set of guidance callouts designed to provide a coherent enrichment experience for students who are interested in learning more about electricity or who have met and exceeded the performance expectations.

Included as an optional handout in this lesson is a reading about electricity for students who want to go deeper. The reading is not included in the student materials. This reading describes the parallels between forces at a distance due to electricity and forces at a distance due to magnetism. It describes how we can use electric fields to explain the energy transferred by electricity in circuits, just as we use magnetic fields to explain energy transferred by magnets. The reading also explains what voltage is and how that relates to the changing current that we discovered in Lesson 8. This is a level 9 reading, so consider using a close-reading protocol to scaffold the reading.

Finally, students are directed to a PhET computer interactive to test out some of their ideas about voltage and electric shocks. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

SCIENCE LITERACY: READING COLLECTION 4

Noncontact Energy Transfer

1 **Unplugged**
2 **Touchless Music**
3 **The Triboelectric Effect**
4 **SciFi or SciFact?**
5 **Magnet and Motor**

Literacy Objectives

- ✓ Use reading to explain how energy can be transferred without any contact between objects.
- ✓ Differentiate between science fiction and fact.
- ✓ Follow directions to build a simple motor.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 7–9.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a description of an invention that uses noncontact forces to solve problems or create new experiences in response to the reading.

Instructional Resources

Student Reader

Collection 4

Science Literacy Student Reader, Collection 4
"Noncontact Energy Transfer"

Exercise Page

EP 4

Science Literacy Exercise Page
EP 4

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 7: How does changing the distance between two magnets affect the amount of energy transferred out of the field?
- Lesson 8: How does the energy transferred from a battery to a wire coil compare to the energy transferred from a computer to a speaker?
- Lesson 9: How do the magnet and the electromagnet work together to move the speaker?

Standards and Dimensions

NGSS Performance Expectation MS-PS2-3: (Building toward) Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

Disciplinary Core Ideas PS2.B: Types of Interactions; **PS3.A:** Definitions of Energy

Science and Engineering Practices: Asking Questions; Constructing an Explanation

Crosscutting Concepts: Cause and Effect; Systems and System Models

CCSS

English Language Arts

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

W.8.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Exercise Page

EP 4

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations.

MONDAY

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Forces at a Distance unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *In "Unplugged," you will find out how you can charge your phone without plugging it in.*
    - *In the second selection, you'll read about a musical instrument that creates sound without touching or blowing through it.*
    - *"The Triboelectric Effect" explains how you can control static cling so your clothes don't stick to you, especially in dry weather.*
    - *In "SciFi or SciFact?" you'll examine and debunk some myths to learn whether certain phenomena are science fiction or science facts.*
    - *"Magnet and Motor" gives you directions to make a simple electromagnetic motor for fun.*

- Distribute Exercise Page 4. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to create a description of an invention that uses noncontact energy transfer.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

WEDNESDAY

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
How is a wireless cell phone charger different from a wired charger?	*A wired charger requires you to plug a cord into your phone. With a wireless charger, you just set the phone on top of the charger, and there are no cords.*
How do different musical instruments create sound?	*On string instruments, you either strum with your fingers, rub the strings with a bow, or hit keys that hit the strings. You blow into brass and wind instruments. You hit or shake a percussion instrument. Electronic instruments use electromagnets to create sounds when you touch the controls.*
What do you do to control static electricity in your clothes or hair?	*Wet clothes or hair with water. Use hair conditioner. Use dryer sheets for clothes.*
What is science fiction?	*Science fiction is a fictional story based on some kind of science adventure or exploration that seems like it could be scientifically accurate but is most often not.*

Suggested prompt	Sample student response
How do you tell the difference between science fiction and science facts?	*Check the source of information to make sure it is credible. Look at the sources used. Find out if other credible sources support the facts or ideas.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How is energy transferred through a wired connection?	*A source of energy from a battery or electrical outlet establishes a current that can then be use to transform electrical energy into another type of energy.*
What is common to energy transferred using forces like magnetism, static electricity, or gravity?	*The forces are noncontact ones.*

Refer students to the Exercise Page 4. Provide more specific guidance about expectations for students' deliverables due at the end of the week.

Exercise Page

EP 4

- *The writing expectation for this assignment is to describe a new invention that uses noncontact forces to save time or labor or provides a new experience.*
- *In the selections, you read about how wireless chargers, a musical instrument, and antistatic clothing transform energy from one form to another without touching or using wired connections.*
- *Think about what you read and know about noncontact forces.*
- *What inventions can you imagine that could use noncontact forces?*
- *Make a list of at least five different inventions.*
- *Choose one invention, and create a description of it and how it works using noncontact forces.*
- *Make your description engaging with examples and graphics. Explain how it uses noncontact forces to save time or work or to create a new experience. A great description will make your readers want to make sure your invention is produced.*

Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

FRIDAY

Facilitate class discussion about the reading collection and writing exercise.

Student Reader

Collection 4

The five reading selections translate understanding of noncontact forces into real-world applications. The readings cover noncontact forces of gravity, static electricity, and magnetism used in wireless chargers, antistatic clothing, and musical instruments. Students also read about the difference between science fiction and fact, with the understanding that yesterday's science fiction can become future science fact. The last selection provides directions for building a simple electromagnet so students can understand firsthand how noncontact forces such as magnetism can be used to transform one form of energy to another.

Page 28 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Unplugged"?	*It describes how the noncontact force of magnetism can be used to charge a phone.* *It explains how wireless chargers work.*
Why do the wireless chargers and the devices they charge need to be very close?	*The device must be within the magnetic field of the charger for the energy to be transferred.*
What are other appliances and tools that would benefit from wireless chargers?	*Any hand tool, like an electric drill or eggbeater or appliance like a vacuum, would be so much easier to use if it didn't have to be plugged in and have a cord to deal with.*

Page 29 Suggested prompts	Sample student responses
How does the second selection help you build knowledge on top of what you learned in the first selection?	*This selection describes a completely different use of noncontact forces.* *This selection explains how noncontact forces can create music.*
Would the theremin work without electricity?	*No, an electromagnet produces the electric field that creates the pitch and volume.*
What would it take to make the theremin able to be charged with a wireless charger?	*The theremin would need to have a magnetic receiving device installed and linked to the emitting device.*

Pages 30–31 Suggested prompts	Sample student responses
What is the general purpose of the third article, "The Triboelectric Effect"?	*This selection explains how noncontact forces can be used to prevent static buildup in clothing.*
How does electrostatic discharge protective clothing work?	*It is a certain weave of fabric that protects the body from static electricity and directs it to the ground.* *It stops the buildup of static electricity that can cause sparks.*
In what occupations can static electricity in clothing be dangerous?	*any occupation that deals with explosives or very delicate material that cannot be disrupted*
What does triboelectric mean?	*a charge of electricity generated by friction, like rubbing a balloon against your hair*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Some students may benefit from a demonstration of how a wireless charger works. Some students may be unfamiliar with or confused by the concept of something being wireless.

CHALLENGE—Have interested students research different types of wireless chargers and compare/contrast them. Invite them to present their findings to the class, including information about whether all wireless chargers contain similar parts or mechanisms that make them work.

CHALLENGE—Invite students to research devices or pieces of technology that have appeared in science fiction movies or books from the past that are real products used today (e.g., cell phones, stun guns).

Pages 32–33 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth article, "SciFi or SciFact?	*This selection explains the difference between science fiction and science facts.* *Science fiction is something that is made up. It is not real, even though it could be based on real scientific concepts or phenomena.* *Science facts are things that can be proved.*
What are some of your favorite science fiction books or movies?	*Student favorites will vary.* They could include things such as Dune, Star Wars, Star Trek, The Matrix, Back to the Future, and Aliens.
Why is it important to distinguish between science fiction and science fact?	*It is important to know what is real and what is pretend.* *You would be greatly misinformed if you believe in some of the science fiction myths that are out there.* *Confirming scientific facts makes you better informed about the natural and human-made world.*

EXTEND—Have students watch a video that shows how to play the theremin.

EXTEND—Have students watch a video about problems with static electricity.

Pages 34–35 **Suggested prompts**	**Sample student responses**
How does the last selection relate to the other selections in this collection?	*It gives directions for creating an electromagnet, which is the device used in many machines and devices that depend on noncontact forces.*
What is a monopole or homopole motor?	*a simple type of motor that uses current electricity and a magnetic field to transform energy for a specific purpose*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 4, students should create a description of a product invention that uses noncontact forces to save time or labor or provide new experiences.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 10

How does distance affect the strength of force pairs in a magnetic field?

Previous Lesson

We added to our list the cause-and-effect relationships that we figured out in Lessons 7 and 8. Then we constructed a classroom consensus model to explain these relationships and how they work together to produce the patterns of movement we see in the speaker. After a brainstorm and a reading jigsaw, we wondered what we could do to make magnetic force strong enough to lift trains and cars.

This Lesson

Investigation

3 DAYS

We are wondering about how magnets can be strong enough to lift a train. We co-design an investigation using a digital scale to test the relationship between distance and magnetic force. We graph our data, which show a nonlinear relationship between our independent and dependent variables. Our data provide more evidence that as distance between magnets and between magnets and test objects increases, the magnetic force decreases. Thus, when the distance between the two magnets is small, as in our speaker, the magnetic force is greater. We have more questions about what causes changes in the strength of magnetic forces that we want to investigate next.

Next Lesson

We will make predictions about what we could change about a system that would make the magnetic force stronger between two magnets, and then we will test our predictions. We will then use a computer interactive to observe the effects of these changes across the entire magnetic field.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Plan an investigation to produce data to support hypotheses about the cause-and-effect relationship between distance and magnetic forces, including identifying independent and dependent variables.

Construct and use a graphical display of data to identify patterns in the mathematical relationship between distance and magnetic forces that can be used as evidence to either support or refute a hypothesis.

What Students Will Figure Out

- The magnetic field around a magnet (and thus an electromagnet) gets stronger when it is closer to another magnet, which means that the force between two magnets will be stronger as the magnets get closer together.

- The force with which a magnet pulls or pushes on something attracted to it or repelled by it is dependent on the distance between the magnet and the object or between two magnets.
- Where magnets are in relation to each other determines how much potential energy is in the system.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	15 min	**NAVIGATION: REVIEW QUESTIONS ON THE DQB** Review questions on the DQB related to the magnitude of forces or the relationship between distance and strength of forces in the magnetic field. Students identify what they already know about the relationship between distance and the strength of magnetic forces, prompted by two brief demonstrations of distance and magnetic force.	A	2 disc magnets, 2 bar magnets, chart paper, marker, DQB
2	30 min	**CO-DESIGNING AN INVESTIGATION** Students work together to plan an investigation to determine the relationship between distance and magnetic force. Students identify important variables they will change and control and determine how they will measure the effects of the independent variable on the dependent variable.	B-F	*Investigating the Effects of Distance on Magnetic Force*, 1 digital scale, 1 small disc magnet taped to scale, 4 stacked disc magnets, 1 ruler, Investigating the effects of distance on magnetic force
				End of day 1
3	15 min	**NAVIGATION** Students discuss their ideas for organizing and analyzing data in the investigation and prepare a data table and graph.	G-I	*Investigating the Effects of Distance on Magnetic Force*
4	25 min	**CONDUCT AN INVESTIGATION** Students conduct the investigation in small groups.	J-K	*Investigating the Effects of Distance on Magnetic Force*, 1 digital scale, 1 small disc magnet taped to scale, 4 stacked disc magnets, 2 different colored pencils, 1 ruler
5	5 min	**NAVIGATION AND EXIT TICKET** Students clean up their investigations and complete an exit ticket.	L	scrap of paper for exit ticket
				End of day 2
6	30 min	**ANALYZE AND INTERPRET THE DATA** Students graph their data and interpret the results in small groups.	L-N	2 different colored pencils, 1 ruler (for graphing), *Investigating the Effects of Distance on Magnetic Force*

7	15 min	**MAKE SENSE OF THE RELATIONSHIP BETWEEN DISTANCE AND MAGNETIC FORCE** Facilitate a Building Understandings Discussion to draw evidence-based conclusions about the relationship between distance and magnetic force.	O-P	Cause-Effect Tracker poster (created in Lessons 6 and 9)

End of day 3

Lesson 10 • Materials List

	per student	per group	per class
Investigating the effects of distance on magnetic force materials			
Lesson materials **Student Procedure Guide** **Student Work Pages**	• 2 disc magnets • science notebook • *Investigating the Effects of Distance on Magnetic Force* • scrap of paper for exit ticket • 2 different colored pencils • 1 ruler (for graphing)	• 1 digital scale • 1 small disc magnet taped to scale • 4 stacked disc magnets • 2 different colored pencils • 1 ruler	• 2 bar magnets • chart paper • marker • DQB • 1 digital scale • 1 small disc magnet taped to scale • 4 stacked disc magnets • 1 ruler • Cause-Effect Tracker poster (created in Lessons 6 and 9)

Materials preparation (25 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Investigation: Investigating the effects of distance on magnetic force

- **Group size:** 3-4
- **Setup:** Prepare lab bins for small-group investigations. Each bin should include 1 digital scale, 5 disc magnets of equal size (¾″ diameter), 2 different colored pencils (i.e., red and blue), and 1 ruler. Students will need access to 3-4 inches of tape to tape one magnet to the scale.
  - The disc magnets should be pre-labeled with small stickers to indicate polarity. Use a compass to identify the north pole of one disc magnet (the south pole of the compass needle will point to the north pole of the disc magnet). Place a sticker on the north pole of the disc magnet. Use this labeled disc magnet as your tool to find

and label the north pole of the other disc magnets. The north pole of each disc magnet should be labeled with a sticker before students begin the lab. This will help students quickly identify like versus opposite poles.

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

The focus of this lesson is on the relationship between the distance between magnets and the strength of magnetic force pairs. This relationship is helpful for understanding more about the magnetic field and magnitude of forces that could be exerted at different locations in the field. The force with which something is attracted to or repelled by a magnet is dependent on the distance between the magnet and the object.

In the speaker, the disc magnet is very close in proximity to the coil of wire. The distance between the two is almost impossible to detect without closely examining the space where the coil of wire is located. This space between the magnets reduces friction as the electromagnet moves back and forth. The distance between the two magnets is slight to ensure the magnetic force between the two magnets is maximized.

Where We Are NOT Going

In this lesson, students use a scale to measure force. Explain that this force is due to gravity in order to help students understand why weight is a measure of force. Students know about force pairs and have the conceptual tools they need to understand that gravity is a force between two objects. In Unit 8.4 Earth in Space, students will get the chance to make these connections. We do not recommend spending time on this here.

1. Navigation: Review questions on the DQB.

15 MIN

Materials: 2 disc magnets, 2 bar magnets, chart paper, marker, DQB

Remind students why we are interested in force strength. Say, *Last time we met, we put the pieces together and developed a consensus model for the speaker. We also did some research into other applications for this kind of technology. We read about magnets that can lift entire trains and make them move hundreds of miles per hour. We read about magnets that can make cars go zero to sixty in less than 2 seconds. We read about magnets that can pick up cars, trucks, and tons of junkyard scrap effortlessly and then drop it somewhere else. All these applications for magnets were very impressive and made us wonder about how people build magnets that can apply forces strong enough to do all those things. Our little electromagnets from our homemade speakers could barely move a paper clip, let alone lift up a passenger train!*

Hold up two bar magnets with like poles facing each other. Keep the poles about 6 inches apart. Ask your students, *What could we do to increase the strength of the magnetic forces between two magnets?*

Listen for these ideas:

- Bring the magnets closer together.
- Get bigger magnets.
- Get stronger magnets.

Give every student two disc magnets. Say, *Orient the magnets so that the magnets are repulsive, like one magnet is a MagLev train and one magnet is the track.* Instruct the students to decrease the distance between the two magnets by half and describe what they feel. Then ask the students to move the magnets farther apart (by about 6 inches) and describe what they feel. Look for students to describe more repulsive forces when the magnets are closer together.

Say, *Well, the closest together the magnets could be is touching. Can someone who read about MagLev trains remind me why we don't want the train to be touching the tracks?* Look for a student to remind the class that friction will slow the train down.

Introduce the need to quantify forces. Say, *OK, so we want the train to be as close to the track as possible in order to get the strongest forces without actually touching the track. We know this because it felt like the forces were bigger when we moved the two magnets closer together. But is this enough to say "build the train this way"? A train is a big, expensive thing to engineer, and it is really heavy. We need to know exactly how much force we can get out of the field and exactly how close the train needs to be on the tracks.* Display **slide A**. Say, *What does it mean to be exact when we are measuring forces? Turn and talk with a partner.*

Elicit student ideas. Look for students to suggest using numbers or units or measuring force with a device of some kind. Say, *When we measure something with numbers in order to be more exact, we call it quantifying.*

Look for questions on the DQB about distance. Say, *This is a cause-and-effect relationship that we want to be able to measure exactly, or quantify. Last time, we made a list of questions about cause-and-effect relationships. Do we have any questions on our DQB about how distance might affect the strength of magnetic forces?* Ask a student to check the DQB section we created in Lesson 9: "Questions about the strength of forces in a magnetic field."

*** Attending to Equity**

This is the first time in this unit we have introduced the word *quantify*. If you are keeping track of vocabulary in a personal glossary or word wall, add it now.

To support all students, and particularly emergent multilinguals, break down the word *quantify*. Ask students to brainstorm other words that start like quantify in English or another language (quantity, quantitative, *cuantificar*). Note that these all have to do with counting. In fact, *count* and *quant-* sound similar and may both come from the same root. Then ask students about the end of the word: *-ify*. Ask, *What other English words end this way?* Look for students to suggest words like *horrify*, *diversify*, *unify*, *qualify*. Point out that all these words mean to make something more of whatever comes at the front of the word. For example, *unify* means to make something more united. *Diversify* means to make something more diverse. So *quantify* must mean "to make something more countable." Consider using this as the definition for the word wall or personal glossary.

- If there are multiple questions related to distance, take a class vote to choose one question to investigate today.
- If there are not any questions on the DQB related to distance, ask partner pairs to work together to write a question about the effect of distance on the strength of magnetic forces, and choose one of these questions.
- Make sure the chosen question links distance to strength and, ideally, is in the format that we established in Lesson 9: When we___[change to system]__will we observe __[effect on system]___? For example, the question might read: When we move the magnets closer together, will we observe the magnetic forces get stronger?
- Record the chosen investigation question at the top of a piece of blank chart paper.

2. Co-Designing an Investigation

30 MIN

Materials: Investigating the effects of distance on magnetic force, science notebook, *Investigating the Effects of Distance on Magnetic Force*, 1 digital scale, 1 small disc magnet taped to scale, 4 stacked disc magnets, 1 ruler

Motivate the measurement of force. Point to the investigation question that the class agreed on. Ask, *In order to answer this question in a very exact way, what do we need to quantify?* Listen for students to suggest that we need to measure the distance between the magnets and the changes in forces between them. Ask, *How do we measure force?* Take all student ideas and tell students that you have a tool for measuring force.

Introduce the digital scale as a measurement tool.* Display **slide B** and ask students to recall the spring scales used to measure forces in collisions in the Broken Things unit and to measure forces from moving air pushing on something in the Storms unit. Remind students that we also used digital scales in that unit to measure the downward force on an object due to gravity. Explain to students, *When a person steps on a scale, the scale measures the net force of the person's body being pulled toward Earth. So, an object's weight is a measure of that downward force.*

Show students the scale with a magnet taped to it and then hold up a group of stacked magnets above the scale. Very briefly, explain how to use the scale to quantify and measure the forces between the single magnet and the stacked magnets. Students will have more time to process this later.

Additional Guidance

Students will record the force of the magnets pushing and pulling on each other as weight, in ounces. The decision to use ounces instead of grams was deliberate in this case. Ounces is a measure of weight or force. Grams is a measure of mass.

Frame a hypothesis for the investigation. Say, *Before we investigate this relationship between distance and magnetic forces we should develop a hypothesis. To help us do this, can anyone name the important parts of the system we are investigating?* Allow one or two students to answer and listen for them to include two magnets. If they think the measurement tools are part of the system, ask, *What is the purpose of the measurement tools?* Listen for ideas about data collection and explain that the ruler will allow us to measure distance in the field and the scale will allow us to measure the forces applied to a magnet.

Display **slide C** and explain to students that they already have a number of experiences that suggest distance affects magnetic forces. They can use these experiences to help them make predictions about the relationship between distance and force, and the results of the investigation will be useful evidence to support or disprove their predictions. Remind students of the sentence frame we have been using to write hypotheses:

If _explanation/theory_ , then when we _cause_ we will observe _effect_ .

Say, *Our theory is that distance affects magnetic forces. Work with a partner to come up with the cause-effect relationships that you predict will tell us something about the effect of distance on magnetic forces.* Give students time to discuss and record hypotheses in their notebooks.

Develop consensus hypotheses in whole group. Ask, *Does anyone want to share their hypothesis to get us started?* If there are no volunteers, call on a student who you noticed through observations of partner conversations has a well-developed hypothesis.

Students might come up with a single hypothesis:

- If distance affects the strength of magnetic forces, then when we move two magnets closer to and further from each other, we will observe the force on the scale changing.

Students might also come up with two hypotheses:

- If a smaller distance between the magnets makes the forces stronger, then when we move two magnets closer together, we will observe the forces on the scale getting higher.
- If a smaller distance between the magnets makes the forces stronger, then when we move two magnets further apart, we will observe the forces on the scale getting lower.

Additional Guidance

We do not expect students to come up with a mechanistic theory that explains why closer distance makes the forces stronger. Rather, students should develop a qualitative description of a mathematical model, as in the examples above. If students do have a mechanistic element to the clause after the if statement, that is also fine.

Co-design the investigation. Pass out copies of *Investigating the Effects of Distance on Magnetic Force.* Explain to students that the class needs to agree on how to conduct the investigation. Show students the materials they will use: a scale with a magnet taped to it, a ruler, and four more connected disc magnets. Use **slide D** to demonstrate the system and discuss the different variables to change or control while conducting the investigation.

Work through the handout together to record the consensus hypothesis that the class came to consensus on earlier in the lesson, which you recorded at the top of a piece of chart paper. Then record the independent variable (distance), the dependent variable (force or weight), and the controlled variables (e.g. type of magnet). As students record these variables on their handouts, record them publicly below the investigation question on the chart paper at the front of the room. Remind students that each variable corresponds to a part of our cause-effect scaffold.

Use the following questions to guide the discussion about variables:

- What is the part of the system we are varying or changing? *This is called our independent variable, and it is the cause in our cause-effect relationship.*
- What is the part of the system we think we will see change as a result? *This is called our dependent variable, and it is the effect in our cause-effect relationship.*
- What do we need to keep exactly the same? *These are controlled variables.*

Preview the procedures. Use **slide E** to preview the steps of the lab with your students. As you demonstrate to students how to use the scale, pause to facilitate a brief discussion about zeroing the scale. Say, *The magnet on the scale is already showing a force reading in ounces. What can I do to make certain we're **only** measuring the force from the magnetic field and not the force of Earth pulling on this magnet on the scale?* Listen for ideas students have about subtracting or canceling out the weight of the magnet and/or taring the scale.

Show students how to zero the scale to achieve this goal of canceling out the weight of the magnet from the system by pressing the "T," or tare, button. Make sure the scale is still tared to zero when there are no other magnets nearby. Remind students to check this throughout their investigation. Once the scale reads zero, demonstrate how to hover the four stacked disc magnets over the magnet taped to the scale.

Once you demonstrate how to hover the stacked magnets over the one on the scale, discuss how to set up the ruler to measure distance. Students should (1) stand the ruler vertically on the table behind the scale, (2) mark a starting point that is eye-level with the top of the magnet on the scale (this starting point will not be zero), (3) measure the distance between the magnets (e.g., 1 cm apart, 2 cm apart, and so forth), and (4) record the force reading to the nearest 0.01 (hundredth) oz on their data table.

Suggested prompts	Sample student responses
When I hover the stacked magnets over the magnet taped to the scale, what do you think I will see happen to the reading on the scale?	*If the magnets are attracted to each other, the measurement on the scale will decrease.* *If the magnets are repelling each other, the measurement on the scale will increase.*
Why?	*If the magnets are pulling on each other, the magnet taped to the scale will push with less force on the scale.* *If the magnets are pushing on each other, the magnet taped to the scale will push with more force on the scale.*

Say, *Let's try that out to see what kind of measurements we get for pulling and pushing forces between the magnets.*

Use the ruler to create a distance of 1 cm between the magnet on the scale and the 4 stacked magnets. Then move the 4 stacked magnets directly up and down between 1 cm and 6 cm apart from the magnet taped to the scale. Explain to students that it is very important to keep the magnets directly in line to collect accurate measurements. Students will initially just move the magnets to notice a pattern. They will then need to make a careful measurement at each distance to record in their data table.

Demonstrate attractive and repulsive forces between the taped magnet and the stacked magnets by flipping the orientation of the stacked magnets. Attractive forces will cause the scale to register negative values. Say, *Wow, it looks like the scale shows a negative force or weight when the force is attractive! Scientists and engineers often use positive and negative numbers to show that a force is going in one direction vs. an opposite direction. In this case, a positive number appears to correspond with a push downward toward the scale and a negative number corresponds with a pull in the opposite direction, or away from the scale. That will be helpful to remember when we are doing our investigations tomorrow.*

Navigate to the next day. Display **slide F** and say, *Talk with a partner about the ways you think we might organize and analyze the data we gather from this investigation. Be prepared to share your ideas when we start class next time.* Save at least three minutes at the end of class for this turn and talk.

End of day 1

3. Navigation

15 MIN

Materials: *Investigating the Effects of Distance on Magnetic Force*

Turn and talk. Display **slide G**. Ask a few students to share their thinking from the turn and talk. Listen for ideas about using tables and graphs. If students don't come up with these ideas, ask, *How would a data table be helpful?* And, *If we were to plot data from a table on a graph, how would that help us?*

Additional Guidance

Many students falsely believe that a hypothesis is only a well-informed hunch or an educated guess. A well-developed hypothesis is not a prediction alone but a statement that articulates a predicted cause-and-effect relationship that we would observe if a certain explanation, theory, or qualitative mathematical model is true. Giving students an opportunity to consider what data will support or refute their hypotheses helps them understand that a hypothesis is never "proven correct" but is supported or not supported by evidence from investigations.

As students are drawing their predictions, they are representing the mathematical model articulated in their hypotheses. Student predictions do not need to be elaborate graphs but rather rough sketches and shapes. Look for students to represent trends (upward, downward, fluctuating, or unchanging).

Discuss how to record data in a data table and transfer it to a graph.* Students will first record their data in a data table in part D of *Investigating the Effects of Distance on Magnetic Force*, and then they will plot their data on a graph in part E. Use **slide H** to help students understand how to record and plot their data. A data table is provided, but the *x*- and *y*-axes are not labeled on the slide or the student handout to increase the rigor of this activity. If students struggle to determine appropriate labels and scales for their graphs, give small groups an opportunity to try on their own and then propose ideas for class discussion. Take time in whole group to ensure that graphs are set up and labeled correctly. Having students add labels and scales themselves, even if they are determined with guidance, will be more meaningful than providing the information to them without time for discussion. Spend time talking about the *x*-axis (distance in cm) and the *y*-axis (force in oz $\times 10^2$), giving particular attention to discussing the negative numbers on the graph. Also remind students how to convert the ounces from hundredths (0.01) to whole numbers by multiplying by 100. Students will use their data to plot points on the graph. They may then connect the plot points to form a line graph and complete their key.

Students make predictions. Display **slide I**. Tell students to make two rough sketches in part C of their handouts. One graph should be a prediction of what the data plot would look like if their data **support** their hypothesis, and the other should be if their data **do not support** their hypothesis. Give students at least 10 minutes for this. These should be rough sketches, and they do not need to label their axes.

*** Supporting Students in Engaging in Using Mathematical and Computational Thinking**

Students will record their data both in a data table and as a graphical representation. Students may be more familiar with graphing data from their math classes, so consider coordinating your approach to this graphing activity with your math colleagues. It is helpful to use similar language in science to that which students hear in math class to foster connections between the disciplines (e.g., "rate" in math and "speed" in science are essentially calculated through similar formulas and graphing activities). This particular activity emphasizes to students the construction and use of mathematical representations, like graphs, to support scientific conclusions and to answer scientific questions. Students will primarily be looking for numerical relationships in their data and will find that the relationship between distance and magnetic force is a nonlinear relationship with a negative association. Students who are taking advanced math classes may also notice that the

Assessment Opportunity

Circulate the classroom to support students who need graphing help. Use this as an opportunity to assess the level of support your students will need while graphing. Look for students who

- do not know what a graph looks like and don't know where to start or
- are creating bar charts or some other kind of graph.

If students need extra support, consider speaking with a math teacher before the next class to coordinate your approach. Spend time as needed on day 3 supporting students in setting up graphs for data analysis. Walk through the I^2 strategy to help students make sense of their data. See callout boxes and Additional Guidance at the end of this lesson for more graphing support.

Say, *I think we are ready to conduct our investigation and collect data.* Students may not have time to graph their data today. Make sure students know that they will have more time to graph and interpret their data in the next class meeting.

relationship is an inverse square relationship. Highlight this idea, but remember that graphing and developing algebraic equations to describe scientific relationships are a high school target for NGSS.

4. Conduct an investigation.

25 MIN

Materials: science notebook, *Investigating the Effects of Distance on Magnetic Force*, 1 digital scale, 1 small disc magnet taped to scale, 4 stacked disc magnets, 2 different colored pencils, 1 ruler

Set up the investigation. Arrange students in groups of 3-4. Ask one member from each group to collect a bin of supplies. Groups need to tape one disc magnet to the scale. They should tape the magnet with the sticker side (north pole) facing upward. Display **slide J**, which includes the investigation setup procedures. Give students five minutes to set up the experiment.

Troubleshoot data collection issues. Ask, *Before we take our data, let's make sure we have considered some of the issues that might come up during data collection. Did anybody notice something that might be a problem for collecting data?* Look for students to note that it was difficult to get a single number on the scale, and it seemed to be jumping around. Then say, *Let's brainstorm some solutions to this. What can we do to keep our hands steady? And if the scale won't settle on a number, what can we do to make sure we are being consistent about the number we choose?* Students might suggest using a pencil to help stabilize the hand of the person holding the magnets. They might suggest choosing the highest or lowest number they see on the scale or a middle number. Some students might suggest taking an average of the highest and lowest number. Come to consensus on a set of solutions and have students record the chosen strategy in part B of *Investigating the Effects of Distance on Magnetic Force* under the text, "What are important things to think about when taking good measurements? List ideas here to help you remember to do these things when you complete the lab."

Conduct the investigation. Display **slide K** with the investigation procedures. Leave at least 15 minutes for students to collect data. Monitor the time and circulate among the groups.

Switch the orientation of the magnet. After about 10 minutes for collecting data on repulsive forces, prompt students to flip the magnets in their hand to see what happens when they have attractive forces between the magnets. Prompt students to use a different colored pencil to record these new data. Give students another 5 minutes to continue to collect their data (part D of *Investigating the Effects of Distance on Magnetic Force*).

5. Navigation and Exit Ticket

5 MIN

Materials: scrap of paper for exit ticket

Respond to an exit ticket to reflect on our process. Say, *Next time we will spend some more time graphing and analyzing our data.* Display **slide L**. Say, *Earlier today, you made two predictions about the graphs you will make. One was a prediction of what the data plot would look like if your hypothesis is supported by the data. The other is what the data plot would look like if your hypothesis turns out not to be supported by the data. Why do you think this is a useful exercise for scientists?* Have students respond to the question on the slide as an exit ticket.

End of day 2

6. Analyze and interpret the data.

30 MIN

Materials: 2 different colored pencils, 1 ruler (for graphing), *Investigating the Effects of Distance on Magnetic Force*

Discuss the exit tickets. Display **slide L** again. Spend no more than 5 minutes asking students to share their responses and ideas. Accept all responses and revoice student ideas related to the nature of science, such as the following:

- It is important for scientists to consider this beforehand so that they are less biased.
- It is important to think about what the data will look like so that we can easily tell if it supports our hypothesis.
- It is important to think about what the data won't look like so that we can easily tell if it does not support our hypothesis, especially if the results are a little messy or somewhere in between the ideal data and the null hypothesis data.

Graph the data. Show **slide M**. Have students graph their data in part E of *Investigating the Effects of Distance on Magnetic Force*. Circulate the classroom to support students as they graph. Prompt students to use one colored pencil to graph their data for repulsive forces and another color to graph attractive forces. Use this opportunity to assist students who may struggle with graphing data points.

Sample data

	Distance apart (cm)					
	1	2	3	4	5	6
Repulsive forces	0.49 oz	0.11 oz	0.07 oz	0.03 oz	0.01 oz	0.01 oz
Attractive forces	-0.51 oz	-0.17 oz	-0.07 oz	-0.03 oz	-0.01 oz	-0.01 oz

Sample data after multiplying force values by 100

	Distance apart (cm)					
	1	2	3	4	5	6
Repulsive forces	49	11	7	3	1	0
Attractive forces	-51	-17	-7	-3	-1	-1

Additional Guidance

Students will record their data to the nearest hundredth of an ounce (0.01). In order to graph the data more easily, students will multiply their data by 100 to get whole numbers. Be sure students understand that because you are multiplying all data values for force by the same factor, any patterns and trends will not be affected. Take this opportunity to point out the use of scientific notation for the values of data to produce the graph ($n \times 10^2$). Students may be familiar with scientific notation from their math class as it is an expected Common Core math standard (CCSS.Math.Content.8.EE.A.4: Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used).

Interpret results in small groups. Display **slide N** and distribute *The Identify and Interpret (I^2) Strategy - Student Guide*. Use the information on the slide to explain the I^2 strategy to students. The handout provides examples if students struggle to get started. Pause after each step to provide any clarification as needed. This process will help students make sense of their graphs. Give students at least 5-10 minutes to engage with this strategy.

Give students another 5-10 minutes to work with their group on the questions in part F of *Investigating the Effects of Distance on Magnetic Force*. They should discuss their ideas and record initial answers to these questions and be ready to share with the class.

7. Make sense of the relationship between distance and magnetic force.

15 MIN

Materials: science notebook, Cause-Effect Tracker poster (created in Lessons 6 and 9)

Facilitate a Building Understandings Discussion. Display **slide O**. Before the whole-group discussion, ask students to turn and talk with a partner in response to the question on the slide. Be sure to use cause-effect language to help students articulate patterns in their data. Ask, *When we changed the independent variable, what pattern in the dependent variable did we observe?**

Display **slide P**. Ask groups to share what they conclude about the relationship between distance and magnetic force based on the first two questions on their handout and their graph interpretations.

1. When we changed the distance between magnets, what pattern in attractive forces did you observe?
2. When we changed the distance between magnets, what pattern in repulsive forces did you observe?

Record this relationship on the Cause-Effect Tracker poster at the front of the room. If there is not enough room, add another sheet of chart paper. The class will add to this again in Lesson 11.

Make a connection to energy. Say, *In Lesson 9, we decided that the way that magnets are arranged in a field affects how much energy is stored in the field. Did we figure out anything today that either supports or does not support that idea?* Look for students to say that our conclusions support the idea that the arrangement of the magnets affects the energy stored in the field because stronger forces means that more energy will be transferred out of the field when we let go of the magnets.

Navigate to the next lesson. Say, *We have a lot of questions left to investigate about the strength of forces. Let's tackle these next time. Maybe we can break into small groups and divide and conquer.*

*** Supporting Students in Developing and Using Patterns**
Recognizing patterns is an important part of analyzing and interpreting data collected during investigations. From their graph, students should identify that there is a pattern in the relationship between *x* and *y* values. From math class, students may identify the relationship as an inverse square relationship or at least a nonlinear relationship. It is not important for students to name this relationship. Students should use this pattern as evidence to support an explanation of the cause-and-effect relationship between distance and magnetic forces.

Additional Guidance

Electricity extension opportunity

Lessons 8-12 include a set of Additional Guidance callouts designed to provide a coherent enrichment experience for students who are interested in learning more about electricity or who have met and exceeded the performance expectations.

In Lesson 11, students will plan and carry out an experiment in small groups. For students who are following the extension path, this represents an opportunity for them to plan an experiment individually in the context of electricity. Consider asking these students to design an additional experiment as home learning to answer the following question: *When we change the distance between two charged objects, do the electrical forces get stronger?* These students should turn in

- a hypothesis,
- a set of procedures,
- a list of materials, and
- a prediction about the results.

ADDITIONAL LESSON 10 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.8.SP.A.1: Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

In this lesson, students will record data from their investigation in a table and use these data to create a graph that allows them to look for patterns of association between the distance between two magnets and the strength of magnetic forces. As students work, ask them to explain their thinking, correspondence between tabular data and graphed data, and any regularity and trends they notice. For attractive forces, students should notice a nonlinear positive association: as x increases, y increases. For repulsive forces, students should notice a nonlinear negative association: as x increases, y decreases. It is possible that students won't have this vocabulary, depending on how this lesson aligns with content in students' math course, but they can describe trends qualitatively.

Students may struggle with accurately creating a scale for their data. A common graphing error occurs when students equally space the data points they collect instead of creating valid scales. Provide scaffolding as needed to ensure students create appropriate scales on the x- and y-axes. You can give students time to grapple with this in small groups and then come to a consensus as a whole group. Another option is to let students work in partners and create graphs using digital graphing platforms (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) or using graphing calculators. Collaboration with math colleagues can provide additional insight into the use of these tools.

If students struggle to interpret their graphs, it may be helpful to add context using the concrete lab investigation setup. Ask them to represent where certain points on their graphs are by holding the stacked magnets above the magnet fixed to the balance.

Supporting Students in Making Connections in Math

CCSS.MATH.8.F.B.5: Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

In this lesson, students gather data describing the effect of changing the distance between two magnets on the strength of the magnetic force pairs between them. They use these data to describe and graph functions that represent the relationships between distance and force for attractive and repulsive forces.

Students will figure out that the relationship between distance and force is not linear. Some students may recognize the pattern on the graph as an exponential relationship, depending on their math experience. Students may know that a functional relationship has only one output for each input. They may think that because there are two data sets and two curves on their graphs, there are two different relationships represented. To help students understand that their data for attractive forces and repulsive forces represent the same relationship even though there are two distinct curves on their graphs, ask them about the symmetry of the curves. You can use tracing paper to show them reflection across the axis. They should notice that the two curves mirror each other. It is important for students to translate their interpretation of the graph into a single relationship between distance and the strength of magnetic forces.

LESSON 11

What else determines the strength of the force pairs between two magnets in a magnetic field?

Previous Lesson

We were wondering about how magnets can be strong enough to lift a train, so we co-designed an investigation using a digital scale to test the relationship between distance and magnetic force. Our data provided more evidence that as distance between magnets and between magnets and test objects increases, the magnetic force decreases. We had more questions about what causes changes in the strength of magnetic forces that we want to investigate next.

This Lesson

Investigation

3 DAYS

We make predictions about what else we could change about a system that would make the magnetic force between two magnets (or a magnet and an electromagnet) stronger and then test our ideas in small groups. Each group investigates an independent variable. We graph our data to establish that the forces get stronger when we make the magnet bigger, increase the number of coils, decrease the diameter of the coils, or increase the current by adding more batteries. We use computer interactives to observe the effects of the changes on the entire magnetic field that we made in our experiments. We establish that magnetic forces can vary in strength across a field and that the whole field can get stronger when you change things about the system.

Next Lesson

We will take stock of how far we have come and apply our new ideas about the strength of forces to both the speaker and the other electromagnet applications we have considered. We will revisit the DQB one last time. Finally, we will take an assessment to demonstrate how much we have figured out about forces at a distance, cause and effect, and designing investigations.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Plan and carry out an investigation to produce data to support a hypothesis about what factors cause changes in the strength of magnetic forces.

Analyze and interpret data to identify linear and nonlinear relationships between various independent variables and their effect on the strength of magnetic forces.

What Students Will Figure Out

- Magnetic forces can vary in strength across a field, and the whole field can get stronger and bigger when you make the magnet stronger.

- Bigger magnets have stronger magnetic fields around them than smaller magnets of the same material, which means that the forces between two magnets will be stronger.
- You can increase the current or the number of coils to get a stronger magnetic field around an electromagnet, which means that the forces between a magnet and an electromagnet will be stronger.

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	15 min	**NAVIGATION** Revisit the questions we had about magnetic strength and compile independent, dependent, and controlled variables for the investigations to come.	A-B	DQB
2	15 min	**PLANNING INVESTIGATIONS** Students work in small groups to plan an investigation for one of the class predictions to determine how varying one thing about the system affects the strength of magnetic forces. Students write hypotheses and identify independent, dependent, and controlled variables.	C-F	*Investigation Plan*, *Peer-Feedback Rubric for Planning Investigations*, What affects the strength of magnetic forces?
3	15 min	**PEER FEEDBACK ON INVESTIGATION PLANS** Students give feedback on their peers' investigation plans.	G	
				End of day 1
4	8 min	**NAVIGATION** Students go over the peer feedback and make modifications to their experimental design.	G	*Investigation Plan*, *Peer-Feedback Rubric for Planning Investigations*
5	15 min	**CARRY OUT THE INVESTIGATION** Student groups investigate one of the variables identified by the class by varying one thing about the system and measuring the effect on magnetic force.	H	*Peer-Feedback Rubric for Planning Investigations*, What affects the strength of magnetic forces?
6	10 min	**MAKE SENSE OF DATA** Student groups graph their data and analyze graphs to reveal patterns.	I-K	*Investigation Plan*, chart paper, markers
7	12 min	**GALLERY WALK** Students display their posters and visit their classmates' posters to gather ideas and leave feedback. Introduce an optional home learning opportunity about the strength of Earth's magnetic field.	L	*Strong or Weak?*, sticky notes, pen
				End of day 2

Part	Duration	Summary	Slide	Materials
8	5 min	**NAVIGATION** Students return to their posters and discuss feedback as a group.		poster
9	15 min	**SHARING FINDINGS IN SCIENTISTS CIRCLE** Students meet in a Scientists Circle and engage in a Building Consensus Discussion to agree on the patterns that emerged in this investigation.	M-O	chart paper, markers, Cause-Effect Tracker poster
10	22 min	**COMPUTER INTERACTIVE** Students make and test predictions about how the changes they made to the system in their experiments will affect the entire magnetic field using a simulation.	P-Q	*Interactive Predictions and Results*
11	2 min	**NAVIGATION AND HOME LEARNING** Assign home learning for students to begin putting the pieces together about the speaker in preparation for the last lesson in the unit.	R	*Cause-Effect Chain, List of Cause-Effect Relationships We Figured Out* (prepared beforehand)
				End of day 3
		SCIENCE LITERACY ROUTINE		Student Reader Collection 5: *Magnetism and Bodies*

Lesson 11 • Materials List

	per student	per group	per class
What affects the strength of magnetic forces? materials		• 1 medium disc magnet • 1 electronic scale • clear tape • 1 ruler	• 8 small disc magnets • 2 medium disc magnets • 2 extra-small disc magnets • 2 large disc magnets • 16 D-cell batteries • 1 roll of 28-gauge magnet wire • 2 copper coils from the speaker • 2 rulers • sandpaper

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Investigation Plan* • *Peer-Feedback Rubric for Planning Investigations* • *Strong or Weak?* • *Interactive Predictions and Results* • *Cause-Effect Chain* • *List of Cause-Effect Relationships We Figured Out* (prepared beforehand)	• chart paper • markers • sticky notes • pen • poster	• DQB • chart paper • markers • Cause-Effect Tracker poster

Materials preparation (30 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

On day 2, the class will fill out a large table on chart paper that synthesizes the findings from their separate investigations. Consider creating this poster ahead of time.

At the end of this lesson, you will pass out *List of Cause-Effect Relationships We Figured Out*, which is a list of the cause-effect relationships that the class has identified thus far. You will need to create this handout based on the list the class has compiled. You can edit the example handout included in these materials, or you can create your own. You might also photograph the class Cause-Effect Tracker poster and make a copy for each student.

Test the Lesson 11 version of the computer interactive on the computers that students will be using. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Investigation: What affects the strength of magnetic forces?

- **Group size:** 3-4
- **Setup:** Prepare lab bins for small-group investigation planning. Groups will use these materials on days 1 and 2 of this lesson. Each bin for a small group should include 1 medium disc magnet, 1 electronic scale, clear tape, and 1 ruler.
- Set out whole-class lab materials at the front of the room: 8 small disc magnets, sandpaper (for removing the enamel covering on the ends of wire), 2 medium disc magnets, 2 extra-small disc magnets, 2 large disc magnets, 16 D-cell batteries, 1 roll of 28-gauge magnet wire, 2 copper coils from the speaker, and 2 rulers. Students will observe this equipment on day 1 and select items for investigations on day 2.
- Test the scales to make sure they have batteries and will tare accurately.
- Test the batteries students will use to make sure they are still good. You can test each of these using the incandescent lightbulbs from Lesson 8.

- Use the following steps to prepare the computer simulation:
  - Reserve computers or tablets for students to use during day 3 of this lesson.
  - Have the website approved for use by your school or district: Concord Consortium Magnet Interactive. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - Test to make sure students can access the interactive's URL from the school's computers.

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will develop the idea that changing certain physical characteristics of a system with a magnet (or magnets) in it can change the strength of the magnetic field it produces, which means that the forces on a test magnet moving into the field will change. Some of the factors they will discover that can affect the magnetic forces include the size of the magnet, the number of coils in an electromagnet, the diameter of the coils in an electromagnet, and the amount of current traveling through the coils of an electromagnet. In a home reading, students will also consider the strength of Earth's magnetic field.

Where We Are NOT Going

Although lines are often used as pictorial representations of the size and direction of a magnetic field, magnetic field lines do not actually exist. Throughout this unit, the magnetic field is represented with pointers to indicate direction of forces in the field to avoid misconceptions and to reinforce that a magnetic field is a continuous three-dimensional invisible physical object around a magnet.

1. Navigation

15 MIN

Materials: science notebook, DQB

Set the purpose for the lesson. Say, *In Lesson 10 we figured out a pretty important relationship about how changes in distance cause changes in the strength of magnetic forces. But we still have a lot of other questions about how we can change the strength of magnetic forces in magnetic fields.* Display **slide A**. Say, *So let's make that our lesson question for today: What else determines the strength of the force pairs between two magnets in a magnetic field?* Ask students to record this lesson question in their notebooks.

Organize independent variables. Say, *Let's go back to the questions we compiled about this in Lesson 9.* Quickly revisit the DQB sections where you kept track of the questions that students wrote in Lesson 9. They should mostly be in this format: When we ___[change to system]__, will we observe __[effect on system]___? Read each question aloud, and then for each one ask, *What change do we need to be able to make to the system to investigate this?*

Display **slide B**. Label a piece of chart paper "Changes we want to investigate." Be sure to leave a little room above the title because you will be retitling the poster later. Then for each investigable question, record the change that will need to be made to the system. If the change is already listed, do not write it again. If the change cannot be made in the classroom, do not add it to the list. Instead, highlight that this question cannot be investigated within the scope of our classroom due the limited materials we have available and move it back to the DQB, out of the special category you created in Lesson 9. You should end up with something similar to the following list:

1. Change the magnet diameter.
2. Change the thickness of the magnet (by stacking multiple magnets).
3. Change the coil diameter.
4. Change the number of loops in the coil.
5. Change the strength of the battery or current to the coil.

Once the list is compiled, say, *We have a name for the variables we have listed here, the changes we are making to the system. Take a minute with your partner to look back in your notebook and discuss what is the general term we use for this type of variable. When you have an idea, raise your hand.* Give students a minute even if hands are already raised so that everyone gets a chance to do the thinking. Then call on a student. Look for students to remember that we call these "independent variables." When the class agrees on this term, cross out the title on the poster we just made and write "Possible Independent Variables" above it.

Give students a chance to add additional independent variables. If your list is complete, you can skip this step. Otherwise, say, *Your group will investigate one of these independent variables today. Before we start, let's make sure we have all our ideas represented here. Besides changing the distance between the objects, what else do we think we can do to the system to make the magnetic forces between magnets stronger or weaker? What about between a magnet and an electromagnet? Turn and talk with a partner.*

Give students several more minutes to talk with their partners. Then solicit ideas to add to the list. If the list is still incomplete after a couple of minutes, begin to suggest changes to the system. Use the prompts below for some ideas.

Suggested prompts	Sample student responses	Follow-up questions
What does it mean to make the magnet bigger?	*We could make it have a bigger diameter.*	*Let's record that idea. Is there any other way to make the magnet bigger?*
	We could make it thicker.	*Let's keep track of both of these changes as different independent variables.*
I have magnets with different diameters, but they are all the same thickness. How could we test our questions about the thickness of the magnet?	*We could stick multiple small magnets together like we did in the distance investigation.*	*Can we make the coil bigger in the same way?*
These are all about the permanent magnet. What would make the magnetic force stronger around the coil?	*make the coil bigger*	*How can we do that?*
What does it mean to make the coil bigger?	*make the circle bigger (increase the diameter of the circle)*	*Let's record that idea. Is there any other way to make the coil bigger?*
	make more coils (make it thicker)	*Let's keep track of both of these changes as different independent variables.*
What else can we change about the electromagnet other than the coils?	*make the current stronger*	*Let's record that. I have an idea about how to do that by putting multiple batteries in series.*

You should end up with a list very similar to the one above. If your students are still struggling to articulate all these changes, you can directly suggest a change to the class. If students suggest a change that can't be investigated now, explicitly label this as an interesting question that cannot be investigated within the scope of the classroom. If students suggest something that is not on the list above but that can be investigated within the scope of your classroom, consider including it in the jigsaw activity.

Consider variables that we need to hold constant. Say, *Now that we know distance is an important factor in the strength of magnetic forces, how can we be sure distance doesn't influence our results as we investigate other factors?* Allow 2-3 students to answer and listen for ideas about keeping the distance constant.

Say, *We will need to use our rulers to help us make sure we hold distance constant as we investigate and measure the effect of other factors so that the distance doesn't influence our results. Because we are keeping distance fixed in this investigation, it will be one of our controlled variables. You will decide in your groups on any other variables that you need to control.*

Additional Guidance

Don't prescribe a height measurement for the investigation at this point. Student groups should be able to make this decision as they plan their investigation. If you notice students are struggling with this during investigation planning, tell them to look back at Lesson 10 to see where the magnetic forces were easiest to measure.

2. Planning Investigations

15 MIN

Materials: What affects the strength of magnetic forces?, *Investigation Plan*, *Peer-Feedback Rubric for Planning Investigations*

Work in small groups to plan an investigation. Display **slide C**. Divide students into groups of 3 to 4. Assign each group one of the five independent variables to investigate. Explain to students that each group will collect evidence about how the strength of magnetic forces changes as they vary one thing about the system. If you have a smaller class, consider dividing the students into pairs. If you have a very large class, have multiple small groups consider the same prediction within the constraints of available materials, rather than form larger groups.

Pass out to each student the *Investigation Plan* handout for students to refer to during the investigation and to record their investigation design. Do not have them put these in their notebooks yet as they will be passing them to another group for feedback. Have students record their name and a group identifier (a number, group name, or list of group members) on *Investigation Plan*. Then pass out to every student *Peer-Feedback Rubric for Planning Investigations* to guide students' design of their investigations.

Circulate as students work on *Investigation Plan* and prompt them as needed to develop hypotheses where the connection between the independent and dependent variables and the cause-effect relationships they want to investigate is clear. Examples of acceptable hypotheses include the following:

- If larger magnets have stronger forces, then when we increase the size (or diameter or width) of our magnet, we will observe the forces on the scale increase for repulsive forces and decrease for attractive forces.
- If electromagnets with more loops in their coils have stronger forces, then when we increase the number of loops in a coil, we will observe the forces on the scale increase for repulsive forces and decrease for attractive forces.

Check that students are correctly aligning their hypothesis with the independent variable (cause) and the dependent variable (effect). Ask probing questions to prompt students to articulate these connections.

Display **slide D**. Let students know that you will provide each group with a medium disc magnet, an electronic scale, clear tape, and a ruler for planning. You can set remaining investigation materials out at the front of the class for student reference as they develop a materials list and plan investigation steps for their hypothesis.

As in Lesson 10, students should record force as weight in ounces. You can remind them that they will need to record to the nearest hundredth (0.01) oz and to multiply their data by 100 to get a whole number for easier graphing. Reiterate that any trends in their data will not be affected by this step since they are multiplying all force measurements by the same factor.

Display **slide E**. Give groups time to determine how they will record and analyze data from their investigation. If they are struggling with developing a data table or labeling their graph, tell them to review their investigation from Lesson 10 for guidance.

Display **slide F**. On part E of *Investigation Plan*, have students sketch two rough graphs to indicate what they think will happen in their investigation if their **hypothesis is supported** by data and if their **hypothesis is not supported** by data. Use this opportunity to assess how students' level of comfort with graphing has changed since the beginning of Lesson 10 when they first engaged in this exercise. Look for students to include the following:

- Two graphs, clearly labeled, with one indicating a supported hypothesis and one indicating a null hypothesis
- Lines for both attractive and repulsive forces, labeled (or indicated in a key) on each graph
- For the supported hypothesis graph, one line trends up from zero and one line trends down from zero
- For the unsupported hypothesis graph, any or all lines remain horizontal (unchanging *y* values)

An unlabeled graph for data is also provided in part G of *Investigation Plan*. At this point, students can propose labels for axes indicating the correct placement of the independent and dependent variables. They should wait to develop scales until they consider the values of the data they collect on day 2. Remind students to consider both attractive and repulsive forces and to graph each as a separate line.

3. Peer Feedback on Investigation Plans

15 MIN

Materials: None

Display **slide G**. Say, *Next time we meet, you will carry out the investigations that you planned today. But before you do, I'd like to give each group an opportunity to get some feedback on their investigation plan.* Have students compile all their investigation plans (*Investigation Plan*) and pass the entire pile to another group, preferably one that is investigating a different variable. Then ask each group to distribute the investigation plans to group members and go through the other group's plan together. Each group member should fill out their copy of *Peer-Feedback Rubric for Planning Investigations* to go along with the plan they are looking at. Most likely these will all look the same since the group developed the plan together, but this may not always be the case. Encourage students to work together to decide what feedback to give, but to record that feedback individually. Students should then staple *Peer-Feedback Rubric for Planning Investigations* to the back of *Investigation Plan* and hand them in to the teacher for safekeeping and review before they leave class.

Assessment Opportunity

The peer feedback rubric *Peer-Feedback Rubric for Planning Investigations* is designed to be student-facing, unlike some of the other rubrics included in materials. Make sure that students get a copy of the completed rubric back with their investigations. This will allow them to get formative feedback that will support the development of these investigations. It also makes expectations transparent for students so that they will know what is expected of them in the Lesson 12 summative assessment. Move from group to group as they work to make sure that students are giving appropriate and productive feedback.

Collect the investigation plans with the rubrics stapled to them. Check that students are correctly aligning their hypothesis with the independent variable (cause) and the dependent variable (effect) and giving appropriate feedback to other groups when evaluating their hypotheses and investigation plans. If students are struggling to put together an investigation plan and peer feedback does not seem productive, add your comments in another color pen to the peer-feedback rubrics. Give students more time at the beginning of day 2 to address this feedback.

End of day 1

4. Navigation

8 MIN

Materials: *Investigation Plan*, *Peer-Feedback Rubric for Planning Investigations*

Review peer feedback and make changes as needed. Display **slide G**. Give students time to look at the feedback they received from their peers, discuss in their groups, and adjust their investigation plans if necessary based on ideas they may have gotten from reading another group's plan and/or feedback from the rubric.

5. Carry out the investigation.

15 MIN

Materials: What affects the strength of magnetic forces?, *Peer-Feedback Rubric for Planning Investigations*

Display **slide H**. Give student groups time to carry out their investigations and record data. Remind students that the only variable they should change in between measurements is the independent variable and that they should have a plan to make sure that all the other variables stay the same (controlled variables).

Safety Precautions

Students who are investigating the current will need to link their batteries in series. The easiest way to do this is using the groove in a ruler to align the batteries, as shown in the image. They may also tape two pencils parallel to one another on a table, about a centimeter apart, and align the batteries between them. Taping the batteries together will help them maintain a connection.

Tell this group to hook up the batteries to the coil for very brief periods of time (e.g., 30 seconds) and then detach them to let them cool off. Have them start with one battery first and work their way up to larger numbers. Do not let groups use more than 4 batteries. Other groups who are investigating the number of loops or diameter of loops should use only one battery. All groups using batteries should be aware of the potential for overheating and the need to detach the wires from the battery or batteries between each test.

Remind students to completely disassemble equipment when the investigation is complete.

Monitor student groups closely to be sure they are heeding safety precautions.

Additional Guidance

The groups that have the number of coils as their independent variable will need sandpaper to remove the enamel covering on all the ends of wire they are using. They will need to get their different lengths of wire from a fresh spool of wire.

Other groups that start with fresh wire for their investigation will need sandpaper to do this too. Students can also reuse the wire coil their group made in Lesson 1, which will already have the ends sanded.

6. Make sense of data.

10 MIN

Materials: *Investigation Plan*, chart paper, markers

Student graph and interpret data. Display **slide I**. Say, *Work with your group to find a pattern that will help you understand how the factor you investigated affects the strength of magnetic forces. Look back at your hypothesis and decide: Which variables will we graph to help us support or refute our explanation?* Give student groups time to prepare graphs by drawing the *x*- and *y*-axes, determining appropriate scales, and labeling the variables along the axes. If students are struggling to prepare graphs, have them look back at graphs from Lesson 10 and describe how scales were determined. Direct students to graph their data.

Display **slide J**. Have students complete their *Investigation Plan* handout and prepare to share their findings on a poster.*

*** Supporting Students in Engaging in Analyzing and Interpreting Data**

A Framework for K-12 Science Education recommends that middle school students "have opportunities to learn standard techniques for displaying, analyzing, and interpreting data. . ." (p. 63). To support students in displaying and analyzing data, move from group to group and challenge students to explain how their graph supports or refutes their hypothesis. Probe student thinking to clarify their ideas. For students who are struggling to interpret their graphs, consider scaffolding their sensemaking by asking them to simply identify a set of patterns on the graph before thinking about what those patterns mean.

Assessment Opportunity

Circulate around the classroom when students are graphing their data. If students are still struggling with this graphing task, direct them to the graphs they made in Lesson 10. Encourage students to use the I^2 strategy introduced in Lesson 10 to scaffold interpretation of the graphs. See Additional Guidance at the end of Lesson 10 for more support around graphing.

Students make posters. Display **slide K** and tell students they will prepare a poster for a gallery walk with the following information:

- Investigation hypothesis
- Do your data support or refute your hypothesis?
  - If your evidence does not support your hypothesis, describe additional data you want to collect.
- A visual representation of the relationship you described in your claim

Direct students to hang completed posters in the desired location in the room.

7. Gallery Walk

12 MIN

Materials: *Strong or Weak?*, sticky notes, pen

Conduct a gallery walk. Display **slide L**. Each group should stay together as they move from poster to poster and spend at least two minutes at each. Only one group at a time should be at each poster. It is more important for groups to spend sufficient time at fewer posters than it is for each group to visit each poster. For example, if your class created 15 posters, rotate students through so that each group visits 4 posters and each poster is visited by 4 groups. Consider using a bell (or something similar) to signal that groups should rotate. At each poster, groups should identify an interesting or confusing pattern that they notice, write this pattern on a sticky note, and leave that feedback on the poster. Tell students that next time we meet, they will look at this feedback with their group.

Introduce the home learning task. Say, *We learned earlier in this unit that Earth has a magnetic field. Based on what you know about the strength of magnetic forces, do you think Earth is a strong magnet or a weak magnet?* Accept a couple of student ideas. *Then say, I have a home learning reading for you to learn a little more about Earth's magnetic field. Keep an eye out for ideas about the strength of Earth's magnetic field.* You can briefly review the close reading strategies below if there is time.

1. Identify the question(s) you are trying to answer through the reading and write it (or them) at the top of the reading.
2. Read once to understand what the reading is about.
3. Read through a second time to highlight or underline a few Key Ideas that help answer the question(s) you had.
4. Summarize the key idea(s) in your own words and/or diagrams.
5. Jot down new questions that arise from this reading.

End of day 2

8. Navigation

5 MIN

Materials: poster

Student groups discuss feedback. Give each group a minute to notice any patterns in the feedback provided by their classmates. Say, *Take a moment to look at the feedback on your poster. Does the feedback help you see any patterns in your data you may not have noticed before?* Give them a few minutes to discuss the feedback provided by their classmates and share any new ideas or questions with each other. As conversations wind down, ask students to meet in the Scientists Circle.

9. Sharing Findings in Scientists Circle

15 MIN

Materials: chart paper, markers, Cause-Effect Tracker poster

Display **slide M.** Say, *Let's keep track of the patterns we noticed on our Cause-Effect Tracker poster.* Guide students to complete the Cause-Effect Tracker table at the front of the classroom by calling on groups to share their investigation findings. Be sure to ask groups to describe evidence from investigations.

Say, *We identified several cause-and-effect patterns. When we make the magnets bigger, for example, the magnetic forces between magnets are stronger. When we increase the current to the coil, this also makes the magnetic forces stronger. We have been investigating one factor at a time. What can all these data together with what we know about how distance affects the strength of magnetic forces tell us about the magnetic field?*

Allow a few students to respond and highlight ideas that make connections between a single force exerted on an object near the magnet and the magnetic field as a set of possible forces that would be exerted on an object near the magnet in different places.

Display slide N. Use the question on the slide and those shown below to draw out ideas and develop additional ideas about the connection between forces and fields.

Suggested prompts	Sample student responses	Follow-up questions
We have been measuring individual forces in one place near the magnet. What does this tell us about the magnetic field around a magnet?	*It tells us how strong the magnetic field is.*	*What would one force tell us about the whole magnetic field?*
How is one magnetic force related to the whole magnetic field?	*The magnetic field is made out of a lot of forces.*	*Is the magnetic field really made up of forces? Can you tell me more about what you mean by that?*
What is the magnetic field?	*It is a map of the magnetic forces that something would experience if you put it near a magnet.*	*Would anything experience those forces? LIke, if I put this pencil in the magnetic field, would it experience those forces?*
Are all the forces mapped by the magnetic field the same strength?	*No, the magnetic field tells us how strong the forces will be in different places.*	
So if making the magnet bigger makes an individual force between two magnets stronger, what will it do to the field?	*Maybe it will make all the field lines longer.* *Maybe it will make all the forces that are possible stronger.*	

Display **slide O**. Say, *We have been measuring individual forces in one place near the magnet. What could we do to figure out how the changes we made in our investigations are actually impacting the whole magnetic field? Turn and talk with a partner and be ready to share your ideas with the class.*

Elicit several student ideas. Validate student ideas about setting up more complex experiments or mapping forces using iron filings or compass needles. Highlight student ideas about computers or simulations. Do not worry if the idea of computer interactives does not come up naturally.

10. Computer Interactive

22 MIN

Materials: *Interactive Predictions and Results*, science notebook

Introduce the interactive. Say, *One way that scientists test out their predictions when it is too difficult or time consuming to collect enough data is by building a simulation based on what they know. We have been doing this already in Lessons 4, 5, and 9 using a computer interactive. Let's do it again today and test out our predictions about the magnetic field.*

Make predictions about the magnetic field. Display **slide P**. Ask students to gather in small groups and consider what predictions they have about what the magnetic field will look like when they change the variables they were changing the other day. For example, what do they think the magnetic field would look like around a big magnet versus a small magnet? Remind students about the conventions they have developed for diagramming forces in a magnetic field. Point to the photo on **slide P** as a baseline for what the magnetic field looks like before changing anything about the system. Have students record their predictions as diagrams in *Interactive Predictions and Results*.

Say, *Let's make some drawings to record our predictions. You can refer to the poster we made yesterday. For each change that we made to the system, think about what happened to the force. What do you think will happen to the whole field? Draw a picture in the box in the middle column.*

Direct students to use the computer interactive. Display **slide Q**. Send students to the interactive. As they use the interactive, have students fill in the table in their *Interactive Predictions and Results* handout.

Say, *We are going to use the interactive to test our ideas about what the field looks like when we change the same variables we tested in our investigations. Our experiments gave us something this simulation will not be able to provide us. Our experiments gave us quantitative relationships between changes in our independent variable and the strength of the forces in the field. On the other hand, our experiments didn't provide us a way to visualize other changes in the magnetic field. This simulation will allow us to do that. So as you play with the interactive, consider how you can use it to extend our understandings from all the investigations we did last time as a class. Talk with your group about what you notice about the magnetic field when you do this. How do the results in the interactive compare to your predictions? Record what you see in the right column of the table in your Interactive Predictions and Results handout.*

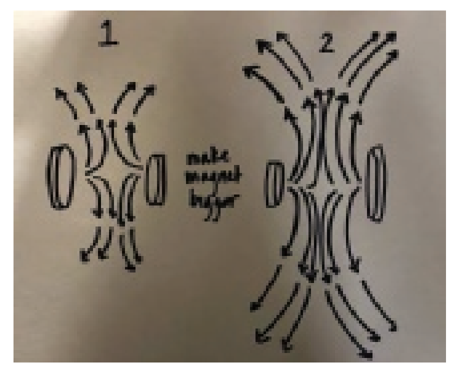
After students have had time to work, say, *It sounds like we have developed several ideas about magnetic fields that help us explain how to make magnetic forces stronger. Let's add to our Progress Tracker.*

Add to the Progress Tracker. Have students fill in the Progress Tracker in their notebooks with the lesson question, *What else determines the strength of the force pairs between two magnets in a magnetic field?*

Ask students to add what they figured out from the investigation and the interactive and to justify their ideas. Look for students to include ideas like these:

- Bigger magnets have stronger magnetic fields around them than smaller magnets of the same material, which means that the force on a magnet from a bigger magnet will be stronger than the force from a smaller magnet.
- You can increase the current or the number of coils to get a stronger magnetic field around a coil of wire, which means that the force on a magnet from the coil of wire will be stronger.

A possible student representation of these ideas is pictured at right.



11. Navigation and Home Learning

2 MIN

Materials: *Cause-Effect Chain*, *List of Cause-Effect Relationships We Figured Out* (prepared beforehand)

Forecast putting the pieces together and the assessment. Say, *Wow, I can't believe how much we have figured out about magnetic forces! Next time, let's take stock of where we have been.* Display **slide R.** Pass out *Cause-Effect Chain* and *List of Cause-Effect Relationships We Figured Out*, which you have prepared beforehand. Tell students that as home learning, they should fill out the cause-effect chain diagram on *Cause-Effect Chain* as best they can. Advise students that they can modify the diagram on the handout to add more boxes to the chain of cause and effect if needed. Tell students that the relationships we added today are not on the handout, so if they think they will need any of them to fill out *Cause-Effect Chain*, they should take a photo or copy them into the handout by hand.

Say, *We will also have an assessment for this unit where you will have an opportunity to demonstrate how much you have figured out about forces at a distance, designing investigations, and cause-effect relationships. This is something you will work on independently at the end of the next lesson.*

Additional Guidance

Electricity extension opportunity

Lessons 8-12 include a set of guidance callouts designed to provide a coherent enrichment experience for students who are interested in learning more about electricity or who have met and exceeded the performance expectations.

For students following this path, ask them to include what they have learned about electron motion in a wire in the cause-effect chain in *Cause-Effect Chain*. Remind them that they can modify the handout to add more boxes to the chain of cause and effect if needed.

SCIENCE LITERACY: READING COLLECTION 5

Magnetism and Bodies

1. **Movie Magnetism**
2. **Are Humans Magnetic?**
3. **Magnetic Treatments**
4. **Magnetic Medicine**

Literacy Objectives

- ✓ Use reading to explain how magnetism affects the human body.
- ✓ Decide whether magnetism is good or bad for or has no effect on the human body.
- ✓ Differentiate between supported and unsupported claims about magnetism.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 10–11.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Develop an argument for whether magnets are good or bad for the human body in response to the reading.

Instructional Resources

Student Reader

Collection 5

Science Literacy Student Reader, Collection 5
"Magnetism and Bodies"

Exercise Page

EP 5

Science Literacy Exercise Page
EP 5

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 10: How does distance affect the strength of force pairs in a magnetic field?
- Lesson 11: What else determines the strength of the force pairs between two magnets in a magnetic field?

Standards and Dimensions

NGSS Performance Expectation MS-PS2-3: (Building toward) Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

Disciplinary Core Ideas PS2.B: Types of Interactions; **PS3.A:** Definitions of Energy

Science and Engineering Practices: Asking Questions; Constructing an Explanation

Crosscutting Concepts: Cause and Effect; Systems and System Models

CCSS

English Language Arts

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

W.8.1: Write arguments to support claims with clear reasons and relevant evidence.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

tesla

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

Exercise Page

EP 5

2. Preview the assignment and set expectations.

MONDAY

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Forces at a Distance unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *In "Movie Magnetism," you will learn about magnetars, which are stars that have powerful magnetic fields.*
    - *In the second selection, you'll read about why your body, with a percentage of iron in your blood, will or will not attract magnets.*
    - *By reading "Magnetic Treatments," you will determine whether claims about the power of magnetic jewelry are supported by scientific evidence.*
    - *"Magnetic Medicine" describes how magnets are used in the medical field to diagnose and treat illnesses.*

- Distribute Exercise Page 5. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to develop an argument for whether magnets are beneficial to, are harmful to, or have no effect on the human body.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

WEDNESDAY

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
Guess how much iron, a magnetic material, is in your body: 50, 25, 10, or less than 1%?	*Males of average height have about 4 grams of iron in their blood, and females have about 3.5 grams. If a person weighs 100 pounds, or 45,360 grams, the amount of iron in the body is way less than 1%.*
Why aren't magnets attracted to or repelled by the human body?	*Human bodies don't have enough magnetic material to affect magnets.*
Why is it believable that magnets have special healing powers?	*Because the body does have some iron in the blood and magnetism is everywhere, it seems likely that magnetism could affect human bodies. And people looking for relief are open to trying different things.*
How can magnets help diagnose and treat human diseases?	*Electromagnets can power many devices and tools that are used in the medical field.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
Why wouldn't humans on Earth be affected by stars that are strongly magnetic?	*We are too far away from these stars. The farther an object is from a magnet, the weaker the magnetic force is.*
Could you increase the strength of a magnet enough so the human body would stick to it?	*You can increase the strength of a magnet by using more current, but because the human body has such little magnetic material, it still would not stick to it.*

Exercise Page

EP 5

Refer students to the Exercise Page 5. Provide more specific guidance about expectations for students' deliverables due at the end of the week.

- *The writing expectation for this assignment is to develop an argument for whether magnets are beneficial to, are harmful to or have no effect on the human body.*
- *In the selections, you read claims about magnetic jewelry and strong magnetic stars that could affect the human body. You also read about magnets used for diagnosing and treating illness.*
- *Think about what you read and know about magnetism and the human body. Do research for additional information. Then make a list of positive, negative, and nonexistent effects that you learn about.*
- *Decide whether magnetism has a positive, negative, or nonexistent effect on the human body.*
- *Write an argument to make your case. Start by stating your position, and then support it with reasons and evidence. Use credible sources to cite your work.*
- *Make your argument persuasive with great examples so your readers will come to agree with you. A great argument will have very clear and persuasive evidence.*

Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

FRIDAY

Student Reader

Collection 5

Facilitate class discussion about the reading collection and writing exercise.

The four reading selections explore different aspects of magnetism's effect on the human body. The magnetic force of megastars would vaporize the human body that came close enough to it, even though the human body contains very little magnetic material. Because of the small amount of magnetic material, it is unlikely that claims about great healing powers of magnets would be supported by evidence. Yet, magnets are used in devices and treatments for human disease.

Pages 36–37 Suggested prompt	Sample student response
What is the general purpose of the first selection, "Movie Magnetism"?	*It demonstrates that although there are super strong magnetic stars, they are not a threat to humans because these stars are so far away.*

Pages 36–37 **Suggested prompt**	**Sample student responses**
What is a magnetar?	*A magnetar would change the shape of all the atoms in a human body if a human came close to it.* *a type of neutron star that has a powerful magnetic field*

Pages 38–39 **Suggested prompts**	**Sample student responses**
How does the second selection help you build knowledge on top of what you learned in the first selection?	*This selection examines how little magnetic material is in the human body so that even strong magnets would not affect it.*
Why don't magnets stick to humans if human blood contains iron?	*There is not enough iron in the blood to have an effect on magnets.*

Pages 40–41 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third article, "Magnetic Treatments"?	*This selection examines claims about magnetic jewelry and its benefits for the human body.* *This selection requires students to identify bad scientific claims related to magnets and human bodies.* *This selection emphasizes how people often seek treatment to improve their health, including trying out magnetic products that claim to help with certain ailments.*
What types of evidence would convince you that magnetic bracelets or stone therapies actually worked?	*There would need to be fair tests and clinical trials done to compare large groups of people who used and did not use a particular product or treatment.* *To be convincing, the results of the tests would show that using the magnetic therapies was clearly superior to not using them.*

Pages 42–44 **Suggested prompt**	**Sample student response**
What is the general purpose of the fourth article, "Magnetic Medicine"?	*This selection describes different scientifically proven devices and tools that use magnets to diagnose and treat human illnesses.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Some students may benefit from breaking the word *endoscope* into its root words. With students, make a list of words with *scope* (*telescope, microscope, periscope*), and discuss how the word *scope* means "to see." The root *endo* means "inside." An endoscope is a tool to look inside the body.

CHALLENGE—Have interested students research different magnetic products or therapies that claim to heal the human body. Ask them to see if they can find any evidence to support the claims. Have them present their findings to the class.

EXTEND—Have students watch a video that explores how an MRI works.

Pages 42–44 Suggested prompts	Sample student responses
What is an MRI, and how does it work?	*An MRI uses strong magnets to generate images of body structures.* *The MRI magnets force protons in the body to align with the magnetic field.* *MRI sensors detect the energy released as protons realign with the magnetic field and can make images of different types of tissues.*
Why is an MRI used instead of an X-ray?	*An X-ray can picture skeletal bones.* *An MRI can picture different soft tissues that could be tumors or other objects that an X-ray cannot detect.*
How does the last selection relate to the other selections in this collection?	*It describes the benefits to human health that magnets can provide, in contrast to unsupported claims and concerns about threats that do not exist.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 5, students should create an argument for whether magnets are beneficial to, are harmful to, or have no effect on the human body.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 12

What cause-effect relationships explain how magnetic forces at a distance make things work?

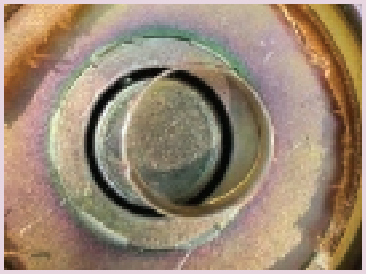
Previous Lesson

We carried out a set of investigations in small groups to establish that magnetic forces become stronger when we make the magnet bigger, increase the number of coils, decrease the diameter of the coils, or increase the current. We used a computer interactive to observe the effects of these changes across the entire magnetic field.

This Lesson

Putting Pieces Together

2 DAYS



We take stock of how far we have come and apply our new ideas about the strength of forces to both the speaker and the other electromagnet applications we have considered. We revisit the DQB one last time to answer our remaining questions. Finally, we take an assessment to demonstrate how much we have figured out about forces at a distance, cause and effect, and designing investigations.

Next Lesson

There is no next lesson.

Building Toward NGSS

MS-PS2-3, MS-PS2-5, MS-PS3-2

What Students Will Do

Revise a model to explain various phenomena that rely on magnetic forces at a distance using a series of cause-effect relationships.

Plan an investigation to determine the effect of changing the metal in an electromagnet on the forces in the system.

What Students Will Figure Out

- Forces transfer energy into and out of a magnetic field.
- The amount of energy stored in the field depends on the strength of the forces (which are affected by several factors) and the arrangement of the magnets in the field.
- Phenomena (like increasing the strength of magnetic forces) can have more than one cause.

Lesson 12 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	15 min	**REVIEWING CAUSE AND EFFECT IN A SCIENTISTS CIRCLE** Students review the list of cause-effect relationships that we uncovered in this unit using their home learning.	A-B	*Cause-Effect Chain*
2	10 min	**APPLY OUR IDEAS IN A SCIENTISTS CIRCLE** Come to consensus around how to explain the Maglev, the motor, and the junkyard magnet, in addition to the speaker.	C-F	chart paper or whiteboard, markers
3	20 min	**REVISIT OUR DRIVING QUESTION BOARD (DQB)** Students revisit the DQB and take stock of all the questions we've now answered.	G	Driving Question Board, 3 colors of sticker dots, chart paper and markers (optional)
				End of day 1
4	5 min	**CELEBRATE AND REFLECT ON OUR EXPERIENCES** Students discuss what was challenging and rewarding about this unit and complete a quick write about their learning experience.	H	
5	40 min	**DEMONSTRATE UNDERSTANDING ON AN ASSESSMENT** Students individually demonstrate understanding on an assessment.	I	*Summative Assessment*
				End of day 2

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	science notebook *Cause-Effect Chain* *Summative Assessment*		chart paper or whiteboard markers Driving Question Board 3 colors of sticker dots chart paper and markers (optional)

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare chart paper for posters.

Online Resources

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

This is the last lesson in unit 8.3. Students do not return to their speaker models in this lesson, but they do get a chance to explain how the speaker works using cause-effect relationships. They also will explain why the gap in the speaker should be as small as possible. Students will also explain how changing various factors about an electromagnet and/or a permanent magnet in a system can increase the forces enough to lift a train or move a car.

Where We Are NOT Going

This unit is about forces at a distance, but the focus is only on magnetism, not on electricity or gravity. In the next unit (8.4: Earth in Space), students will get the opportunity to dig into gravitational interactions and will apply their ideas about fields from this unit to that context.

1. Reviewing Cause and Effect in a Scientists Circle

15 MIN

Materials: science notebook, *Cause-Effect Chain*

Take stock of where we have been. Begin class in a Scientists Circle. Say, *We have come a long way in the past few weeks. We started wondering what was going on inside a speaker, and now we can explain a variety of magnetic phenomena! Let's take a moment to take stock of where we have been.*

Present **slide A** and introduce students to the lesson question, "What cause-effect relationships explain how magnetic forces at a distance make things work?"

Return to the cause-effect home learning. Display **slide B**. Point students to the list of the cause-effect relationships that we have documented at the front of the room and on *Cause-Effect Chain* as part of their home learning. Have students compare their cause-effect chain with a partner and then solicit ideas about how students' chains were similar or different. Say, *Look how far we have come, we can explain how the speaker works using these very complex cause-effect relationships!* Have students put *Cause-Effect Chain* (which they completed for home learning) in their notebooks.

Consider that phenomena can have more than one cause. Say, *We also figured out how to make magnetic forces stronger. What causes changes in the strength of magnetic forces?* Look for students to identify many things.

Then say, *It sounds like there are a lot of things that we can point to as causes. It would be difficult to describe this using a nice chain like the one we worked on for home learning. I think we can say that some phenomena have many causes! Can we think of another example of another phenomenon that has multiple causes?*

Elicit a couple of student ideas, then say, *Cause-effect relationships can be complex. Sometimes phenomena can have more than one cause. And it can be difficult to figure out if one thing causes another thing without setting up an experiment. But as we saw in this unit, cause-and-effect relationships in systems can be a very powerful way for scientists to figure out phenomena.*

Alternate Activity

As an optional way to bring closure to this unit, you might consider giving students a chance to try building their cup speakers again using what they know about how to make magnetic forces stronger. Use the video to preview what this might look like. Give yourself an extra day (45 minutes) if you choose to give students this opportunity. You will need to include all the supplies used in the investigations in Lesson 11 plus the materials from the homemade speaker in Lesson 1. You will also need to set up a station as you did in Lesson 1 for students to test their speakers.

2. Apply our ideas in a Scientists Circle. 10 MIN

Materials: science notebook, chart paper or whiteboard, markers

Explain the Maglev, the motor, and the junkyard magnet. Display **slide C**. Ask, *How have our investigations in Lessons 10 and 11 helped us understand how these very big electromagnets work?* Elicit student ideas. Look for ideas about how engineers could make the magnets stronger by adding more coils, increasing the current, installing larger magnets, and making the gap smaller between the magnets.

Consider applications to the speaker. Display **slide D**. Ask, *What about the speaker? How have the things we learned in Lessons 10 and 11 helped us understand the speaker better?* Look for students to suggest that since a smaller distance means stronger forces, it explains why the gap between the coil of wire and the magnet was so small in the speaker. Students might also consider what these changes might do to the sound in the speaker. For example, adding more coils to the speaker might increase the forces and allow for louder sounds. Changing the current more quickly could mean that it was capable of making higher-pitched sounds.

Wrap up our ideas about energy transfer. Display **slide E**. Ask, *What can we say now about the relationship between forces, energy, and magnetic fields?*

Suggested prompts	Sample student responses
What can we say now about the relationship between forces, energy, and magnetic fields?	*Forces transfer energy into and out of magnetic fields.* *The energy stored in the field is dependent on the arrangement of the magnets.*
Does anything else impact the amount of energy stored in the field? Would there be the same amount of energy in the field between small magnets 3 mm apart as there would be between big magnets 3 mm apart?	*No. The strength of the forces impacts the energy stored too.*

Display **slide F** which summarizes our conclusions about energy, forces, and magnetic fields.

Key Ideas

Purpose of this discussion: The purpose of this discussion is to make explicit some generalizable science ideas about forces and energy in fields.

Listen for Key Ideas that relate to the following science principles.

- Forces transfer energy into the magnetic field, and forces transfer energy out of the magnetic field.
- The amount of energy that is transferred into and stored in the field is determined by the strength of the magnetic forces (which is determined by many causes) and the arrangement of the magnets in the field.

3. Revisit our Driving Question Board (DQB). 20 MIN

Materials: science notebook, Driving Question Board, 3 colors of sticker dots, chart paper and markers (optional)

Frame the activity. Display **slide G**. Say, *We've figured out so much! I bet we can answer many of our questions on the Driving Question Board.**

Mark patterns in questions answered using the sticker dots. Have students stay in a Scientists Circle. Focus the discussion on identifying (1) questions we agree that we can answer, (2) questions that we have at least a partial answer to, and (3) questions we cannot answer at all. Choose one color of sticker dots to mark each of these categories.

Discuss the questions the class can now answer. Have the class discuss the answers to those questions as a whole group. If you have space, you might make a "Takeaways" poster that has a record of the class's answers. Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering questions that were important to them at the onset of the unit.

*** Attending to Equity**
Revisiting the Driving Question Board is important for students to feel as though their questions are valued and recognized. While not all questions will have been addressed (it's more likely that 50–75 percent will be at least partially answered), this helps students see the hard work that they have done to answer many of their own questions.

Assessment Opportunity

While students are answering questions from the Driving Question Board, this is an excellent formative assessment opportunity to address partial understandings and see if any pieces need to be revisited before taking the summative assessment.

End of day 1

4. Celebrate and reflect on our experiences. 5 MIN

Materials: science notebook

Celebrate the class's accomplishments. Say, *I can't believe how far we have come since we first wondered about what was inside a speaker. We should be very proud of what we have accomplished.*

Have students reflect upon their experiences with the unit. Display **slide H**. Ask students to find a new page in their notebook and label it "Reflection." Underneath, they should record their answers to these questions:

- What was most challenging in this unit?
- What was most rewarding?

Alternate Activity

If you have time, you could also structure this reflection as a "blizzard." For a blizzard, have students record their reflections on a piece of loose paper anonymously, crumple it up, and then throw it up in the air. Students can then pick up a ball of paper and go around one by one and read aloud what is on the paper they picked up until everybody's reflection has been shared.

As a whole-group, ask each student to share part of their reflection. Taking time to reflect upon the process of this unit can allow students to think metacognitively about what works well for them as learners.

5. Demonstrate understanding on an assessment.

40 MIN

Materials: *Summative Assessment*, science notebook

Introduce the assessment. Say, *In this unit, we've figured out how a speaker works through examining electromagnets, magnetic fields, forces, and energy. We've read about a couple of other things in the world that use electromagnets to apply a force to something or make something move.*

Display **slide I**. Have students respond to the following question as a Turn and Talk: *Choose one of the applications that we have learned about: Maglevs trains, electric motors, junkyard magnets, or speakers. Why is it useful to have an electromagnet instead of just using a permanent magnet(s) in the system?* After a couple of minutes, transition to a whole-class discussion using the prompt below.

Suggested prompt	Sample student responses
Why is it useful to have an electromagnet instead of just using a permanent magnet(s) in any of these systems?	*The speaker needs to move in both directions in order to make a sound. An electromagnet can be turned on and off, and we can change the polarity and the strength of the forces.* *An electromagnet in a junkyard magnet can be turned on and off so it can pick up a car and then let it go. Not being able to turn it off might also be a waste of electricity.* *In order for the electric motor to work, the coil needs to keep spinning to make the wheels move. So the polarity of the coil needs to be switching constantly, which we can only do with an electromagnet.* *We need to be able to turn the Maglev train on and off because it isn't always being used. We also need to be able to move the train forward by switching the direction of the current.*

Say, *We've been introduced to a few examples of where an electromagnet is used to do something like this. Now I'm wondering, if you could use an electromagnet to apply a force to something or to make something move, what kind of things would you design? Think for 3 minutes and record your ideas in your notebook. Then we'll share our initial ideas as a class.* Show **slide J** to frame the brainstorming task.

During the class discussion, make all student ideas visible. Help weed out ideas that don't require electromagnets by asking probing questions to clarify students' thinking. For example, if a student suggests a giant refrigerator magnet, ask, *Why is it important for there to be an electromagnet in that design? Why couldn't it just be a very strong permanent magnet?* Students may argue that the system needs to have any of the following:

- Times it is on or off
- Times when we need to vary the strength

- Times when reversing the direction of the force is useful
- Times when the patterns in the change over time in any or all of the above are related to supporting some aspect of its function

Administer *Summative Assessment* individually to students. Say, *To wrap up our unit you will choose an electromagnet application from the class list or from a new idea you have and apply your understanding of everything we figured out to that new situation. This is our final individual assessment for the unit*. Have students prepare for the assessment. Pass out one copy of the assessment to each student. This assessment will take students the remainder of the class period to complete. Once completed, students should turn in their assessment to you for feedback.

Assessment Opportunity

This is a transfer task to give students an opportunity to use the 3 dimensions to make sense of an application of an electromagnet of their choice. This assessment is designed to elicit student ideas about forces at a distance as they design an experiment using the cause-effect language they have been practicing throughout this unit.

This is meant to be a summative assessment task for the unit, and it gives you a grading opportunity. The task includes a scoring guide. Scoring guides are meant to highlight important ideas students should include in their responses. If students share these ideas elsewhere in the assessment, it is up to you to decide if that understanding is sufficiently demonstrated.

Note that this assessment is full of student choice and includes a whole-class introduction component to make sure all students are on the same page and have access to ideas brainstormed by the whole class before moving forward with the individual assessment.

Additional Guidance

Electricity extension opportunity

Lessons 8-12 include a set of guidance callouts designed to provide a coherent enrichment experience for students who are interested in learning more about electricity or who have met and exceeded the performance expectations.

Included as an optional handout in this lesson is a transfer task with ideas students have developed about electricity. The task asks students to use a short reading about microphones to reconstruct the series of cause-effect relationships that make the microphone work and then to model a microphone in a diagram.

Teacher Resources

Table of Contents

Assessment System Overview

Each unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1		**Pre Assessment** The student work in lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn where students are coming in and what ideas they have that you can build on in this unit. The more ideas in your classroom the better. Specifically, look for students' initial understandings of modeling, asking questions, systems and systems models, and cause & effect. **Developing and Using Models; Systems and Systems Modeling** **When to check for understanding:** At the end of day 2, collect student notebooks to use their initial models as a pre-assessment. **What to look/listen for:** Look for agreement on the important parts of the system (magnet, coil, speaker cone). Some students should be trying to model interactions, not just drawing the speaker parts. **What to do:** If there is not agreement on the parts of the speaker, spend time at the beginning of class on day 3 coming to consensus on the important parts of the system before considering interactions. More guidance on this is provided in the teacher guide. Make note of the students who are representing interactions between parts, and bring attention to their representations as the class builds their initial models. **Asking Questions; Cause and Effect** **When to check for understanding:** As students are building the DQB on day 3, the class will spend some time using a fill-in-the-blanks scaffold to think about cause and effect. Accept all questions for the DQB, but take note of the kinds of questions students ask after this exercise. **What to look/listen for:** Look for the kinds of questions students are asking. Are they all about cause? Are they all about effect? Are any about the how or why of a cause-and-effect relationship? **What to do:** Point out to students if the balance is off and give them some time to try to fill in the gaps. If students are still having trouble translating the cause-effect framework into questions for the DQB, consider spending some time with more familiar systems, as described in the teacher guide.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 3		**Formative Assessment** This lesson is the first time students build hypotheses — an important component of the asking questions practice. In Lesson 3, for the first time, students frame a hypothesis, which includes not only an observable cause-and-effect pattern, but also the mechanistic explanation that we hope to uncover through an investigation that establishes the pattern. In this lesson (lLesson 3), students begin by identifying changes they can make to the system, and then turning these into predicted cause-effect relationships using the sentence starters. Students then pause to consider what makes these statements hypotheses, rather than simply predictions — that establishing those cause-effect patterns through investigation will either support or disprove a model or explanation for the phenomenon. Students will be building hypotheses throughout the unit. As students are developing their hypotheses during the lesson, look for students who are mixing up what goes in each of the columns, such as these for examples: • If the energy moves through the air, then we will observe the air moving. . . . • If I see the air moving, then we will observe the flag wave. . . . • If I see the flag waving, then we will observe that the energy moves through the air. . . . These are perfectly reasonable ways to state a hypothesis, but they do not fit the structure of the scaffold as the class has been using it. Use probing questions to clarify the purpose of the scaffold. Ask these students, *Is this a change you can actually make to the system? If not, does it belong in this column? Is this an effect that we can actually observe, or an effect that is maybe invisible?*
Lesson 6	L6 Student Assessment L6 Key	**Summative+Formative** This lesson is a putting the pieces together lesson. It includes a summative midpoint assessment that can provide formative information for moving forward in the unit. The teacher reference document provides a scoring guide. This midpoint assessment is important formatively to make sure the class is on the same page and ready to move forward in the unit. At this point, students should be comfortable with the following claims: • If a system contains a permanent magnet and we bring a paperclip near the system, we will feel a pull. • If a system does not contain a permanent magnet and we bring a paperclip near the system, we will not feel a pull, indicating that there are no forces on the paperclip. • Connecting a copper coil to a magnet creates an electromagnet creating an attractive magnet field that creates force pairs with metal objects.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 7		**Formative** In Lesson 7, students develop a hypothesis for the investigation and do some initial planning for the investigation. This is an opportunity to understand students' progress with respect to developing hypotheses and identifying variables in their investigations. **What to look/listen for:** • A hypothesis that addresses how changes in the distance between two magnets (cause) will result in differences in the amount of energy transferred to the cart (effect) when it is released. Ideally students will also be able to identify differences in forces in the field at different distances between the magnets as an intermediate mechanism that can explain these outcomes. • Distance (gap) between the two magnets identified as the independent variable. • Speed of the cart after it is released identified as the dependent variable. • A data table with a record of measurements of distance traveled and travel time from when the cart is released to when it stops moving. • A data table organized to record more than one value for the independent variable. • A data table organized to record more than one trial for the value of the independent variable tested. • Calculation of average speeds for each trial or averaged speeds across multiple trials for each value of the independent variable tested. **What to do:** Leave feedback in the form of noticings and wonderings in the student notebooks, for any area of their investigation plan that students did not develop fully, as outlined above. Return these to students at the start of the next lesson. Examples of such feedback include things like: • *I noticed that you identified distance as your independent variable. I am wondering if you can be more specific in words and/or diagrams to help make your thinking visible, about how you will determine/measure the distance you will be changing.* • *I noticed that you created a data table to record travel time for each trial. I am wondering if this was the time it took the cart to travel cross a certain finish line or if it was the total travel time (from when it started moving to when it stopped moving).*
Lesson 9	L9 Rubric	**Formative** Lesson 9 provides an opportunity for formative assessment of students' models of the speaker system. Students discuss the development of models to explain the speaker system in groups and then individually draw them in their notebooks. Use the rubric to analyze where students are with modeling this system.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 11		**Formative and Summative** In Lesson 11, students work in groups to plan and carry out a complete investigation. This is an opportunity to assess students as they work in groups. You could decide to use their group work as a summative assessment opportunity. We recommend reviewing the investigation plans for formative information and giving students feedback.
Lesson 12	L12 Student Assessment L12 Key	**Summative** This is a transfer task to give students an opportunity to use the 3 dimensions to make sense of an application of an electromagnet of their choice. This assessment is designed to elicit student ideas about forces at a distance as they design an experiment, using the cause-effect language they have been practicing throughout this unit. This is meant to be a summative assessment task for the unit and it gives you a grading opportunity. The task includes a scoring guide. Scoring guides are meant to highlight important ideas students should include in their responses. If students share these ideas elsewhere in the assessment, it is up to you to decide if that understanding is sufficiently demonstrated. Note that this assessment is full of student choice and includes a whole class introduction component to make sure all students are on the same page and have access to ideas brainstormed by the whole class before moving forward with the individual assessment.
After each lesson	Lesson Performance Expectation Assessment Guidance	**Formative Assessment** Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.
Occurs in most lessons	Progress Tracker	**Formative and Student Self Assessment** The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time. In this way, the Progress Tracker can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Tracker is meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative "grade" other than for completion.

When	Assessment and Scoring Guidance	Purpose of Assessment
Anytime after a discussion	Student Self Assessment Discussion Rubric	**Student Self Assessment** The student self assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try next time to improve such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small group discussions can be more productive.
After Students Complete Substantial, Meaningful Work	Peer Feedback Facilitation: A Guide	There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work. Rather, peer feedback will be more valuable to students if they have time to revise after receiving the peer feedback. It should be a formative, not summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.

For more information about the approach to assessment and general program rubrics, visit the Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	Develop an initial model to describe how interactions between parts of a speaker system (magnet and coil of wire) cause sound without those parts touching each other. Ask questions about how interactions between parts of a speaker system (magnet and coil of wire) cause sound without those parts touching each other.	**Developing and Using Models; Systems and Systems Modeling** **When to check for understanding:** At the end of day 2, collect student notebooks to use their initial models as a pre-assessment. **What to look/listen for:** Look for agreement on the important parts of the system (magnet, coil, speaker cone). Some students should be trying to model interactions, not just drawing the speaker parts. **What to do:** If there is not agreement on the parts of the speaker, spend time at the beginning of class on day 3 coming to consensus on the important parts of the system before considering interactions. More guidance on this is provided in the teacher guide. Make note of the students who are representing interactions between parts, and bring attention to their representations as the class builds their initial models. **Asking Questions; Cause and Effect** **When to check for understanding:** As students are building the DQB on day 3, the class will spend some time using a fill-in-the-blanks scaffold to think about cause and effect. Accept all questions for the DQB, but take note of the kinds of questions students ask after this exercise. **What to look/listen for:** Look for the kinds of questions students are asking. Are they all about cause? Are they all about effect? Are any about the how or why of a cause-and-effect relationship? **What to do:** Point out to students if the balance is off and give them some time to try to fill in the gaps. If students are still having trouble translating the cause-effect framework into questions for the DQB, consider spending some time with more familiar systems, as described in the teacher guide.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	Collect data to establish that magnets interact with certain objects to cause paired forces that are either attractive (both pulls) or repulsive (both pushes) and that changing the orientation of either of the magnets will cause both forces to reverse direction. Collect data to answer questions about the coil of wire and provide evidence to support the claim that connecting the coil of wire to a battery causes the same paired forces between the coil and a magnet as between two magnets.	**Investigation; Energy and Forces** **When to check for understanding:** After the investigation of the coil and the magnet on day 2, you will hold a Building Understandings Discussion. **What to look/listen for:** Listen to determine whether students are thinking about both pushes and pulls (repulsive and attractive forces) between the magnet and the coil of wire. Probe student thinking to make sure that students are associating repulsive forces with pushes, where the arrows point outward in the diagram, and attractive forces with pulls, where the arrows point inward in the diagram. If students do not make these associations, it is an indication that they are struggling to connect the data they have collected to the directionality of forces. **What to do:** Consider using the following kinesthetic activity to reinforce the idea of directionality. Have students stand in pairs facing each other. Each pair should choose which student will be the coil connected to the battery and which student will be the magnet. Then ask students to hold up their arms straight toward one another with their hands almost touching and imagine what would happen if they pulled on each other (if you feel comfortable asking your students to gently pull on each other, do so). Did they move toward each other or away? Is this indicative of attraction or repulsion? Do the same exercise for students pushing on each other. Finish by discussing with students how this model works well as an analogy to the wire and magnet system (pushes and pulls bringing things apart and together) and how the model falls short (contact forces versus forces at a distance). **Explanation; Cause and Effect** **When to check for understanding:** At the end of this lesson, students respond to the following question as an exit ticket: Is the coil of wire a magnet? Use at least one cause-effect relationship to justify your response. **What to look/listen for:** Use this exit ticket to determine if students are understanding (1) that the coil of wire exhibits the properties of a magnet only when attached to a battery and (2) how to use cause-effect relationships to justify a claim. Do not worry about whether students respond yes or no but rather how they justify their claim. Students who need more support might have answers that make a claim but either do not justify that claim or do not use both clauses from the cause-effect framework to justify the claim. See assessment guidance box within the lesson for examples of student responses to look for. **What to do:** If necessary, spend some time at the beginning of the next lesson reinforcing the cause-effect structure before moving on to hypothesis building. Remind students that we can use the "when we______, we observe______" sentence structure to talk about our observations when we change something, or we can add the word *will* ("we will observe") to make predictions about what we think will happen when we change something.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 3	Develop and test a set of hypotheses to produce evidence that energy can transfer between magnets without transferring through matter, causing the magnets to move. Construct an argument supported by empirical evidence and scientific reasoning that energy can transfer between magnets without going through matter, causing the magnets to move.	**Questioning; Cause and Effect** **When to check for understanding:** As students work on *Framing Hypotheses*, circulate the room. **What to look/listen for:** Look for students who are mixing up columns, such as these examples: • If the energy moves through the air, then we will observe the air moving . . . • If I see the air moving, then we will observe the flag wave . . . • If I see the flag waving, then we will observe that the energy moves through the air . . . **What to do:** These are logical ways to state a hypothesis, but they do not fit the structure of the scaffold as the class has been using it, and it could set students up for difficulty when they need to distinguish between hypotheses and predictions. Use probing questions to clarify the purpose of the scaffold. Ask these students, *Is this a change you can actually make to the system? If not, does it belong in this column? Is this an effect that we can actually observe or an effect that is maybe invisible?* **Argument; Cause and Effect** **When to check for understanding:** As a home learning opportunity at the end of this lesson, students construct an argument based on the demonstrations we did in class. This is also an assessment opportunity, but keep in mind that argument and explanation are not focal practices for this unit. Students should draw on their previous experience with argumentation and explanation to complete this task. **What to look/listen for:** Look for students to do the following: • make a claim about how air is not involved in energy transfer • provide evidence from either or both demonstrations • connect the evidence to the claim explicitly by explaining why it supports or does not support the hypothesis that air is involved in energy transfer **What to do:** Make note of students who are struggling to connect their claim to the evidence from the demonstrations. Come back to this at the start of the next lesson and ask students to work in pairs to critique each other's explanations and then revise their own. If there is time, consider having students work in groups of three to develop a consensus explanation and share it in a gallery walk, allowing students to leave their critiques as sticky notes on the chart paper. Pair students strategically, putting students with strong explanations together with students who need more support.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 4	Ask questions about the cause and effect relationships that produce the patterns we observed (and will observe) in the direction or size of forces in a magnetic field around a permanent magnet as it interacts with another object(s) near it. Use diagrams and simulations to model the patterns we observe in the forces experienced by test objects placed near a magnet or a coil of wire connected to a battery (magnetic fields).	**Patterns; Modelling** **When to check for understanding:** Throughout this lesson, students keep track in their notebooks of the patterns they see. Collect science notebooks after day 2. **What to look/listen for:** Students should model the direction of the forces as pointing out of the north pole of the magnet and into or toward the south pole of the magnet. They should model the shape as extending all around the magnet in three-dimensional space. **What to do:** If students are not accurately representing the magnetic field at this point, take note of what they are struggling with: Is it the direction? Is it that the magnetic field is only on the ends of the magnet, not all the way around? Then use the simulation on day 4 of this lesson to highlight for students these features of the magnetic field. **When to check for understanding:** In an exit ticket on the last day of this lesson, students will apply what they know about forces in a magnetic field to predict the effect of a second magnet on a compass needle placed in between two magnets. **What to look/listen for:** Do not expect student representations to be accurate. Review these exit tickets for the modeling conventions that the class has used in this lesson for the patterns we see in magnetic fields, including (1) using pointers to indicate the field; (2) illustrating the space around the entire magnet (or magnets), not just on one side; and (3) using pointers coming out of the north pole and into the south pole. **What to do:** If necessary, remind students of these conventions before launching into the first activity of the next lesson. **Asking Questions; Cause & Effect** **When to check for understanding:** During the first day of this lesson there are scaffolding and supports for students to ask questions that arise from careful observation of phenomena to seek additional information. They also ask questions that can be investigated within the scope of the classroom. These two elements of the SEP are emphasized in the first day of this lesson and supported throughout the lesson. You will be able to assess student success with these two elements as students develop, refine, and add their questions to the DQB at the end of day 1. **What to look/listen for:** Look for questions that stem from the observations they have made about magnetic fields with iron filings. Some questions should arise about the direction of the forces to motivate the need to try compasses. Look for questions that are within the scope of the classroom and can be tested in the classroom. Questions that will provide evidence to answer the students' questions are particularly useful. **What to do:** If students struggle with this task, offer them more examples and nonexamples as a means for them to compare the questions. Follow by asking them to offer their own examples and then analyze those questions using the same criteria included in the lesson. **When to check for understanding:** As an exit ticket at the end of the lesson, you have the opportunity to assess students' ability to use cause-and-effect relationships to make predictions.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		What to look/listen for: Do not expect student representations to be accurate. Review these exit tickets for the modeling conventions that the class has been using in this lesson for the patterns we see in magnetic fields, including (1) using pointers to indicate the field; (2) illustrating the space around the entire magnet (or magnets), not just on one side; and (3) pointers coming out of the north pole and into the south pole. Look for students describing the cause-and-effect relationship as they explain or model what happens to the field when two magnets are brought close to each other. **What to do:** Remind students of these conventions before launching into the activity of the next lesson. Have students use their models from previous lessons as a guide for them to sketch their predictions. Have them picture their sketches of two magnetic fields if they were side by side.
Lesson 5	Use a computer interactive to model the effect on the patterns in the magnetic field when we add an electromagnet to the single magnet system.	**Modeling; Cause and effect** **When to check for understanding:** An exit ticket at the end of this lesson is designed to assess students' application of the cause-effect sentence starters to make predictions about how the models they have created will manifest as interactions between magnets when distance or orientation of the magnets change. **What to look/listen for:** An ideal response might look like this: • When we bring the magnets close together when the forces are attractive, then we will observe them move toward each other and stick together. • When we bring the magnets close together when the forces are repulsive, then we will observe them wanting to push away from each other and when we let go they will fly apart. The prediction itself is useful as a tool for motivating the activity in the next lesson. But the most important thing to assess is not the content of the prediction but the students' comfort with using the cause-effect sentence starters to formulate their predictions based on their models. **What to do:** If students are still struggling to apply this structure to their predictions correctly without a more explicit scaffold, consider returning to the Lesson 1 slides introducing the use of the fill-in-the-blank scaffold to describe cause-and-effect relationships. Insert these slides at the beginning of Lesson 6 and use a familiar system (e.g., a falling cell phone) to practice making predictions. You might also consider using a video of a Rube Goldberg machine to practice describing cause and effect.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	Develop an initial model to describe how forces and energy transfer in magnetic fields explain cause and effect relationships between parts of a speaker system (magnet and coil of wire). Ask questions about how interactions between parts of a speaker system (magnet and coil of wire) cause sound without those parts touching each other.	**Summative Assessment** This is a putting-the-pieces-together lesson. It includes a summative midpoint assessment (*Figuring out the doorbell*) that can provide formative information for moving forward in the unit. *Midpoint Assessment: Figuring out the doorbell* provides a scoring guide specific to this assessment. This midpoint assessment is important formatively to make sure the class is on the same page and ready to move forward in the unit. At this point, students should be comfortable with the following claims: • Magnetic force pairs between two magnetic objects can be attractive (pair of pulls) or repulsive (pair of pushes). • A magnet has an invisible field around it that describes the way a test object (like a magnet or a piece of iron) would act if it were brought close to the magnet. • A coil of wire acts like a magnet when it is connected to a battery (or a music player), including having an invisible magnetic field. Students should also feel comfortable using the language of cause and effect to frame hypotheses. **Modeling; Cause and Effect** **When to check for understanding:** Before day 2 of this lesson, review students' exit tickets. The exit tickets will provide valuable information about the kinds of ideas the students will bring to the consensus model and how much scaffolding you will need to provide in order to reveal gaps in the consensus model and motivate Lessons 8 and 9. **What to look/listen for:** Look for at least a couple of students to point out that (1) we are not sure where the energy comes from exactly, 2) we are still not sure why the battery or music player makes the coil into a magnet and 3) we are still not sure why the forces are switching back and forth between pushes and pulls since it doesn't seem like anything is flipping orientation in the speaker. **What to do:** Note who is already considering these gaps and be prepared to call on these students to move the discussion forward on day 2. If nobody is noticing these gaps in the model, be prepared to use probing questions on day 2 to clarify students' explanations and reveal these gaps. **Modeling; Energy and Forces** **When to check for understanding:** Part of building the consensus model will require articulation of the relationship among forces, energy, and magnetic fields. **What to look/listen for:** Pay particular attention to (1) how students layer the magnetic forces on top of the magnetic fields to show the relationship between the two and (2) how they use this relationship to describe force pairs between two objects that can act without contact. In addition, pay attention to the way students talk about energy. Students should be relating energy to forces by talking about how forces cause the object to move by transferring energy to that object.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		What to do: If students are struggling to relate magnetic fields and forces, use the computer interactive to focus their attention on this relationship. If students are still unclear about the relationship between force and energy transfer, review the ideas the class developed in units 8.1 (Broken Things) and 8.2 (Sound Waves) to review forces and energy transfer in the context of physical pushes and pulls, which can be more intuitive.
Lesson 7	Plan and carry out an investigation using a cart on a track to determine how changing the distance between two magnets affects the amount of energy transferred from the field between them. Develop an explanation using results from the investigation to explain the interactions and behavior of the cart system using ideas about forces and potential energy.	**Planning and Carrying Out Investigations, Using Mathematical Thinking; Matter and Energy, Cause and Effect** **When to check for understanding:** On day 1, students develop a hypothesis when they complete *Hypotheses and Variables* and develop an investigation plan on this sheet and on *Data Table and Procedure*. **What to look/listen for** • a hypothesis that addresses how changes in the distance between two magnets (cause) will result in differences in the amount of energy transferred to the cart (effect) when it is released (Ideally students will also be able to identify differences in forces in the field at different distances between the magnets as an intermediate mechanism that can explain these outcomes). **What to do:** Leave feedback in the form of noticings and wonderings in the student notebooks for any area of their investigation plan that students did not develop fully. **Construct an Explanation; Energy Flow, Cause and Effect, Systems and System Models** **When to check for understanding:** Students apply scientific ideas, principles, and evidence to answer three related questions on *Making Sense of Your Investigation Results*. Collect their explanations in *Making Sense of Your Investigation Results* at the end of this lesson. **What to look/listen for** • Energy transfers from the magnetic field into the magnets to make them move. • Energy transfers out of the field and into the magnets for both attractive and repulsive forces, even though the direction of the movement is different. **What to do:** Leave feedback in the form of noticings and wonderings in the student notebooks for any area of their investigation plan that students did not develop fully, as outlined above, and return these to students at the start of the next lesson.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	Ask questions and carry out investigations to answer questions about how the pattern of energy flow compares in different systems using a speaker, a wire coil, a lightbulb, a battery, and a computer. Critically read scientific text to gather evidence to explain the differences in the electric current produced by the computer (the cause) that results in a changing magnetic field within the speaker system (the effect).	**Asking Questions and Carrying Out Investigations; Patterns, Cause and Effect** **When to check for understanding:** These are three points where this happens: 1. They individually answer question B on their exit tickets at the end of day 1 for the class to investigate in the following class. 2. They form hypotheses in small groups in the middle of day 2. 3. They record additional questions at the start of day 3, before sharing these with the whole class. Collect exit tickets at the end of day 1 to assess #1 and collect student notebooks at the end of the lesson (day 3) to assess #2 and #3. **What to look/listen for:** See the assessment callouts below in the *Teacher Guide* for guidance on each assessment opportunity. **What to do:** If some students struggle to develop questions, leave sticky notes (with their initials on them) in their notebooks asking them to record new questions that they have at the end of the next lesson. Then you can collect them to contribute to expanding the Driving Question Board. **Evaluating Information, Cause and Effect** **When to check for understanding:** This happens when students interact with their two-column chart and the reading to add check marks and stars to them both. And it happens as they discuss the bold questions in the reading with a partner and a synthesis question after the reading. **What to look/listen for:** Watch how students interact with their two-column chart and reading to assess how they are evaluating the information they obtain from the reading. Listen in to the conversations they have with a partner during and after the reading. These provide you an opportunity to assess how they are communicating information they have gathered and evaluated. **What to do:** One way to quickly assess students in this practice is to use a class checklist. This checklist would be for the teacher only—not for public display. More information about what this checklist would look like is provided in the assessment guidance within the lesson.
Lesson 9	Revise a model to describe how changes in a magnetic field due to changing electric current explain cause and effect relationships between parts of a speaker system (magnet and coil of wire).	**Developing and Using Models; Systems and Systems Modeling** **When to check for understanding:** Before day 2 of this lesson, review the models students drew/revised in their notebooks at the end of day 1. **What to look/listen for:** Use *Rubric for Model in Lesson 9* to structure your feedback. Note that this rubric is not designed for students to see before they complete their models. **What to do:** Record your feedback on students' models. Students will get time on day 2 of this lesson to review this feedback before moving into consensus building.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
	Ask questions about how changing the speaker system (cause) could affect the strength of the forces in the magnetic field (effect).	**Asking Questions, Cause and Effect** **When to check for understanding:** At the end of this lesson, students spend time in small groups revising and developing questions for the DQB about the strength of forces in a magnetic field. Use the cause-effect sentence frame to focus student thinking: When we____*[change to system]*______will we observe ___*[effect on system]*__________? **What to look/listen for:** Look for students to ask questions about cause-and-effect relationships related to the strength of forces. Look for students to use the language of cause and effect to frame their questions. **What to do:** If students are struggling with how to use the sentence starter to revise a question, use probing questions to help them clarify their thinking around what is the cause and what is the effect. For example, if a student poses the question "What makes the forces bigger?" you can ask these questions: • *Are the size or strength of the forces a cause? Or an effect?* • *What do you think we should investigate that might be causing the forces to get bigger? Can you include that potential cause in the question?* • *Can you rewrite the question to include what you just told me about cause and effect?*
Lesson 10	Plan an investigation to produce data to support hypotheses about the cause-and-effect relationship between distance and magnetic forces, including identifying independent and dependent variables. Construct and use a graphical display of data to identify patterns in the mathematical relationship between distance and magnetic forces that can be used as evidence to either support or refute a hypothesis.	**Planning and Carrying Out an Investigation; Cause and Effect** **When to check for understanding:** Students develop a consensus hypothesis for the relationship between distance and the strength of magnetic forces. **What to look/listen for** • Look for how students translate hypotheses into variables: ◦ The independent variable is the cause described. ◦ The dependent variable is the effect described. • During whole-class co-planning of the investigation, listen for students to plan for varying the independent variable by a quantifiable amount while keeping all other variables constant and measuring the strength of magnetic forces. • During data analysis, students should use patterns in their graphed data to confirm that as distance between magnets increases and decreases, the forces between the magnets change. **What to do** • Observe students as they grapple with developing hypotheses and describing variables. This will provide information about how much scaffolding will be needed in Lesson 11 when students will be expected to do this on their own.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 11	Plan and carry out an investigation to produce data to support a hypothesis about what factors cause changes in the strength of magnetic forces. Analyze and interpret data to identify linear and nonlinear relationships between various independent variables and their effect on the strength of magnetic forces.	**Analyze and Interpret Data; Patterns** **When to check for understanding:** Students make two rough sketches in part C of their handout. One graph should be a prediction of what the data would look like if their data support their hypothesis, and the other should be if their data do not support their hypothesis. These should be rough sketches, and they do not need to label intervals on their axes. **What to look/listen for:** Circulate the classroom to support students who need graphing help. Use this as an opportunity to assess the level of support your students will need while graphing. Look for students who • do not know what a graph looks like and don't know where to start or • are creating bar charts or some other kind of graph. **What to do:** Spend time as needed supporting students in setting up graphs for data analysis. Walk through the I^2 strategy on day 3 to help students make sense of their data. See callouts and additional guidance at the end of this lesson for more graphing support. **Planning and Carrying Out an Investigation; Cause and Effect** **When to check for understanding:** On day 1 of this lesson, students will be planning their investigations in groups. At the end of the day, students give one another feedback using a student-facing rubric (*Peer-Feedback Rubric for Planning Investigations*). Walk around the room as students are giving feedback. After class, check over the peer-feedback rubrics to get a sense for where students are. **What to look/listen for:** Check that students are correctly aligning their hypothesis with the independent variable (cause) and the dependent variable (effect) and giving appropriate feedback to other groups when evaluating their hypotheses and investigation plans. **What to do:** If students are struggling to put together an investigation plan and peer feedback does not seem productive, add your comments in another color pen to the peer-feedback rubrics. Give students time at the beginning of day 2 to address this feedback. **Analyze and Interpret Data; Cause and Effect** **When to check for understanding:** Circulate around the classroom when students are graphing their data on day 2. **What to look/listen for:** Look for students who are still struggling to put together the graph and record the data. **What to do:** If students are still struggling with this graphing task, direct them to the graphs they made in Lesson 10. Use the I^2 strategy handout to scaffold interpretation of the graphs. See Additional Guidance at the end of Lesson 10 for more support around graphing.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 12	Revise a model to explain various phenomena that rely on magnetic forces at a distance using a series of cause-effect relationships. Plan an investigation to determine the effect of changing the metal in an electromagnet on the forces in the system.	**Summative Assessment** This is a putting-the-pieces-together lesson. It includes a summative final assessment and provides a scoring guide specific to this assessment. While students are answering questions from the Driving Question Board at the end of day 1, this is an excellent formative assessment opportunity to address partial understandings and see if any pieces need to be revisited before taking the summative assessment.

Using Cause-Effect Scaffolds to Support Science and Engineering Practices

Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts (NGSS, *Appendix G*, p. 1).

Overview of Cause-Effect Scaffolds in Unit 8.3

Cause and effect is a focal crosscutting concept for this unit. The fill-in-the-blank sentence frames introduced in Lesson 1 will assist students in investigating and explaining causal relationships in the speaker system. In Lesson 6, these sentence frames become a table that students use to organize their thinking about all the interactions in a system that they have figured out. They will come back to these related scaffolds frequently throughout the unit to support the development of several practices and disciplinary core ideas in the context of cause and effect.

The purpose of the cause-effect sentence frames and associated tables is to make the role of this crosscutting concept explicit and salient for students. Students should be actively engaged in using the cause-effect framework in a concrete way to make sense of the phenomenon, not just hear about crosscutting connections passively. Students use the cause-effect scaffold in several different ways throughout the unit, and the sentence frames change slightly to support each use.

Using the Cause-Effect Scaffold to Support Making Observations and Predictions

Students use the cause-effect sentence frames to articulate their observations throughout the unit:

When we *change to the system (cause)* , we observed *effect on system* .

Students also use the sentence frames to make predictions using the following framing:

When we *change (cause)* , we will observe *effect* .

Occasionally, students will be asked to explain their observations or justify their prediction by adding a "because" clause to the end of these frames.

We recommend using "when we . . ., we will observe . . ." for predictions instead of "if . . ., then . . ." so as to prime students for understanding the distinction among predictions, observations, questions, and hypotheses.

Using the Cause-Effect Scaffold to Support Asking Questions

Asking questions is a focal practice in this unit. In Lesson 1, students use the cause-and-effect scaffold to describe cause-and-effect relationships very generally and then to support the development of questions about cause-and-effect relationships. They consider four different types of questions that we can ask about cause-and-effect relationships before taking a second pass at the Driving Question Board (DQB):

1. What is the **effect** on the system (or a part of the system) when we make this change?
2. What is the **change** we would need to make to get this effect? What part(s) is involved in this change?
3. Does this change **cause** this effect? Or could both things be happening for another reason?
4. **How or why** does this change cause this effect?

In Lesson 9, students use the cause-effect sentence frames to ask more-focused investigation questions about cause-effect relationships. They use the following reframing to revise existing DQB questions and ask new questions that they can investigate in the classroom in Lessons 10 and 11.

When we *change to the system (cause)* , will we observe *effect on system* ?

Using the Cause-Effect Scaffold to Support Hypothesis Framing

In middle school, the NGSS specifies that as part of the development of Science and Engineering Practice 1 (Asking Questions), the focal practice for this unit, students are expected to "frame a hypothesis based on observations and scientific principles" but only "when appropriate" (*Appendix F*, p. 5). These words are chosen carefully because asking questions, making predictions, and framing hypotheses are not the same thing. It is important to note the distinction between the types of predictions and questions students have been making up until now and the hypotheses they will write in this unit.

According to *Appendix H* of the NGSS, a hypothesis is an "idea that may contribute important new knowledge for the evaluation of a scientific theory" (p. 5). It is not simply the articulation of a pattern (if this, then that) but rather the articulation of a pattern that, if established, would lend support to a mechanistic model or explanation for a phenomenon. In Lesson 3, for the first time, students frame a *hypothesis*, which includes not only an observable cause-and-effect pattern but also the mechanistic explanation that we hope to uncover through an investigation that establishes the pattern:

If *explanation or theory* , then when we *change (cause)* we will observe *effect* .

Students begin by identifying changes they can make to the system and then turning these into predicted cause-effect relationships using the sentence starters. Students then pause to consider what makes these statements hypotheses rather than simply predictions—that establishing those cause-effect patterns through investigation will either support or disprove a theory, model, or explanation for the phenomenon. Students repeat this process several times throughout the unit, including when they design their own investigations as a class in Lesson 10 and in small groups in Lesson 11.

Note that hypotheses are often framed in elementary school as "if-then" statements. This framing can be problematic when students enter high school. A hypothesis is not the same thing as a prediction. The most important part of the hypothesis is the mechanistic explanation or model, or theory, that the investigation is designed to test. This theory is what should come after the "if" in the statement. A hypothesis statement should articulate a predicted cause-effect relationship only in service of either supporting or refuting the mechanistic explanation that would result in that relationship being true. Students collect data to demonstrate the cause-effect relationship in order to lend support to the mechanistic explanation. We recommend using "when we …, we will observe" for predictions so as to prime students for understanding hypotheses.

Note that in Lesson 3 we choose to introduce theory because it is a commonly used word that appears in the NGSS in reference to hypotheses. According to NGSS *Appendix H*, in middle school students should learn that "theories are explanations for observable phenomena" and that "the term 'theory' as used in science is very different from the common use outside of science" (p. 5). Consider taking a moment to engage students in a conversation about where they have heard the word *theory* before. Students may suggest that a theory is an idea that hasn't been proven or an educated guess.

Sometimes, scientific ideas are said to be "just a theory." This is said about biological evolution, for example, or the link between anthropogenic greenhouse gases and climate change. This use of theory is often deployed in order to make it seem like these ideas are not widely accepted. This use is misleading. In everyday talk, the word *theory* means just a hunch, but in science, a theory is a powerful explanation for a broad set of observed phenomena. A theory must be supported by many different kinds of evidence in order to be accepted by the scientific community. Evolution and anthropogenic climate change are widely accepted by the scientific community. For all students, science is a new language that they need time to develop and become fluent with. Even scientists sometimes use the word *theory* when they really mean an explanation, a hypothesis, or a hunch.

In high school, students will learn that a scientific theory can be disproven when the body of evidence weighs against it. According to NGSS Appendix H, "A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence."

Using the Cause-Effect Scaffold to Support Designing Investigations

The cause-effect scaffold is designed to also support students in determining independent, dependent, and controlled variables and designing investigations to determine the nature of the relationship among these variables. In Lesson 3, for the first time in this unit, students are reintroduced to independent and dependent variables. They then use the sentence frames to identify explicitly the connection among these variables and the cause-effect relationship they want to investigate.

If *explanation or theory*, then when we *independent variable* we will observe *dependent variable*.

Overview of the use of cause-effect sentence frames in Unit 8.3

Observation

When we *change to the system (cause)*, we observed *effect on system*.

Question

When we *change to the system (cause)*, will we observe *effect on system*?

Prediction

When we *change (cause)*, we will observe *effect*.

Hypothesis

If *explanation or theory*, then when we *change (cause)* we will observe *effect*.

Determining variables

If *explanation or theory*, then when we *independent variable*, we will observe *dependent variable*.

Do-It-Yourself 3-D Magnetic Field Viewer

Materials

- 2-3 tsp iron filings (or cut up steel wool)
- 1 clear plastic bottle —any size (flat-sided ones are best)
- mineral or baby oil (enough to completely fill your bottle)
- 1 strong magnet

How to make your own magnetic field viewer

1. Pour a few teaspoonfuls of iron filings into your bottle.
2. Fill your bottle with oil.

Hint: Fill it completely. The goal is to have few or no air bubbles. If your bottle is not rigid, squeeze the bottle before putting on the cap.

3. Wipe off the top of the bottle so you get a good seal.
4. Place the cap tightly on your bottle.
5. Shake up the mixture.

Hint: You will need to shake the bottle often, as the filings will settle.

6. Put a strong magnet next to the bottle and watch the filings map the magnetic field.

Additional Tips and Notes for Success

Most importantly, test your compasses or magnetic needles well ahead of time! Compass needles can be easily thrown off when stored near magnets. We are also finding that the sources of these materials do not consistently paint the compass needle tips the same color or on the end that points north. Sometimes the red or orange tip points north and sometimes it points south. The best thing to do is to test your compasses or magnetic needles early so you have time to problem-solve before the lab. This test process will work the same whether you are using needles or compasses because they are essentially the same thing (except that magnetic needles on their own are rare and compasses are easy to source).

Lay the needles or compasses on a flat surface an inch or two apart. Look at the color tips of the needles to see how the direction they are pointing. All needles should point the same direction and that direction should be magnetic North. You can test the needles/compasses further by bringing a bar magnet near them to see how they respond.

Testing Magnetic Needles

Testing Compasses

What do I do if the needles/compasses are not consistent with one another?

This depends on how many are pointing opposite (which is likely more about how many needles are painted incorrectly).

Lesson 4 requires the use of many needles or compasses. Consider one of the options below.

Option 1: Students can still complete the lab with a single magnetic needle or compass in their group. They simply move their needle/compass around the bar magnet or coil and record the direction the needle is pointing. In this way you need only 10 needles/compasses.

Option 2: Sort the needles or compasses into categories where the needles point the same direction. Provide each group of students a set of compasses that are consistent with one another even if they are not consistent with another group's needles. When the class discusses the lab, talk about whether the same color pointed the same way, but steer students away from whether red/orange or white/silver was pointing north or south since different groups will have seen different things.

Option 3: In addition to option 1 or 2, create a teacher demonstration set students can look at after they complete the lab (see below). This will help them see what the compasses or needles would look like if they place 8-10 around a single bar magnet at the same time.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Figuring out the doorbell

When we bring a magnet near the doorbell when it is not connected to the battery, we feel a pull, or an attractive force.

- This may be because there is a permanent magnet in the doorbell.
- But metals like iron also produce attractive forces when they interact with a magnet, so there could be iron in the doorbell.

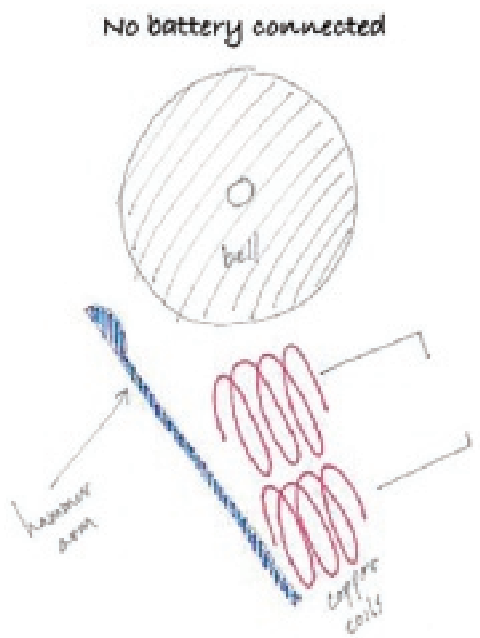
1a. In the first row of the table below, write a hypothesis that describes the cause-effect relationship you would expect if there was no magnet in the doorbell, just metal like iron.

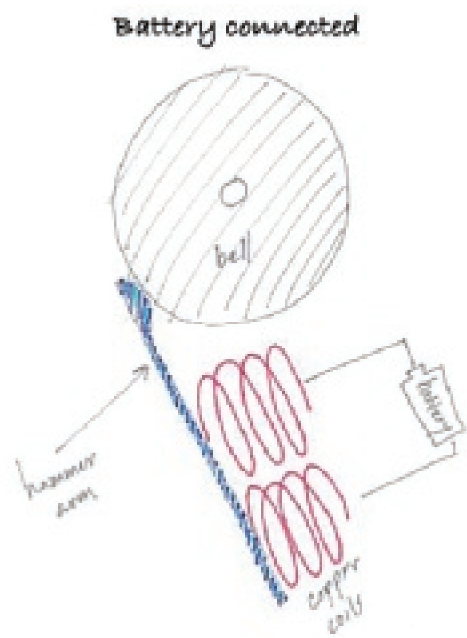
1b. In the second row, write a hypothesis that describes the cause-effect relationship you would expect if there was a magnet in the doorbell.

	Explanation or theory		**Change to the system (cause)**		**Effect on the system**
If	1a. there is no permanent magnet in the doorbell, just metal like iron	**then when we**		**we will observe**	
If	1b. there is a permanent magnet in the doorbell	**then when we**		**we will observe**	

2. A student drew a model of the doorbell. It includes two time points:
   - first, with no battery connected to the coil
   - then, after a battery is connected to the coil

   Complete the student's model after the battery has been connected to the coil to help explain how connecting the battery (cause) causes the doorbell to make a sound (effect). Make sure to include **the forces and the magnetic field in the system**. Label the forces clearly.





Midpoint Assessment: Figuring out the doorbell

1. When we bring a magnet near the doorbell when it is not connected to the battery, we feel a pull, or an attractive force.
   - This may be because there is a permanent magnet in the doorbell.
   - But metals like iron also produce attractive forces when they interact with a magnet, so there could be iron in the doorbell.

a. In the first row of the table below, write a hypothesis that describes the cause-effect relationship you would expect if there was no magnet in the doorbell, just metal like iron.

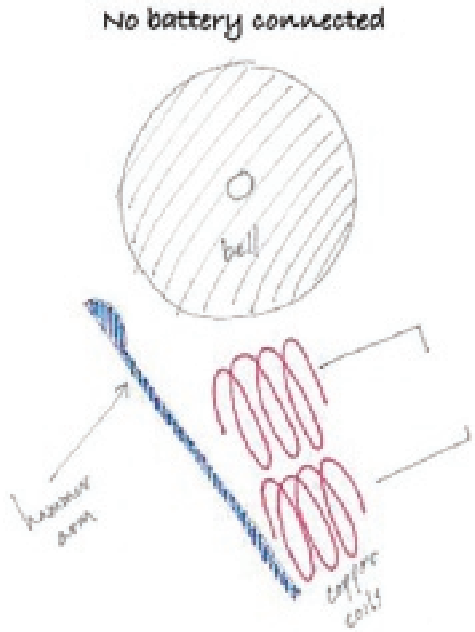
b. In the second row, write a hypothesis that describes the cause-effect relationship you would expect if there was a magnet in the doorbell.

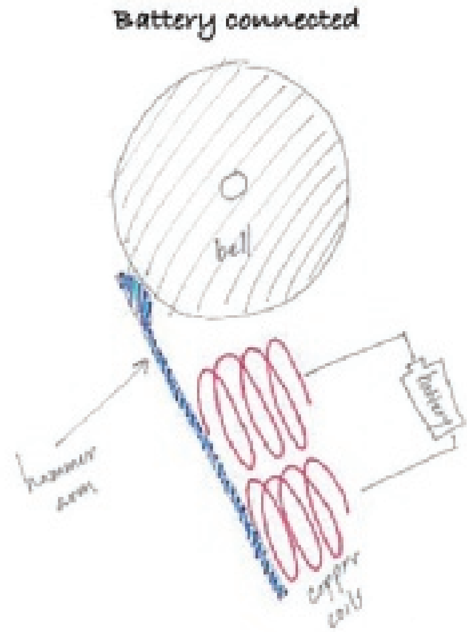
Ideal student response(s)

	Explanation or theory		Change to the system (cause)		Effect on the system
If	1a. there is no permanent magnet in the doorbell, just metal like iron	**then when we**	*+ bring a paper clip near the system* *OR* *+ bring a magnet near the system* *OR* *+ flip the magnet around near the system*	**we will observe**	*+ no forces when the paper clip gets near the system* *OR* *+ pulls no matter which direction the magnet is facing*
If	1b. there is a permanent magnet in the doorbell	**then when we**	*+ bring a paper clip near the system* *OR* *+ bring a magnet near the system* *OR* *+ flip the magnet around near the system*	**we will observe**	*+ pulls when the paper clip gets near the doorbell* *OR* *+ pulls when the magnet gets near the system that turn into pushes when we flip the magnet*

2. A student drew a model of the doorbell. It includes two time points:
   - first, with no battery connected to the coil
   - then, after a battery is connected to the coil

   Complete the student's model after the battery has been connected to the coil to help explain how connecting the battery (cause) causes the doorbell to make a sound (effect). Make sure to include **the forces and the magnetic field in the system**. Label the forces clearly.





- *magnetic field on the coils*

+ Student uses pointers (or some other way to represent magnetic fields agreed on by the class) to indicate direction.

+ Magnetic field is attractive (shape looks something like the picture below, which includes some curvature out of one pole and into the other).

+ Magnetic field is centered in the right place (around one or both coils).

- *accurate forces between coils and hammer arm*

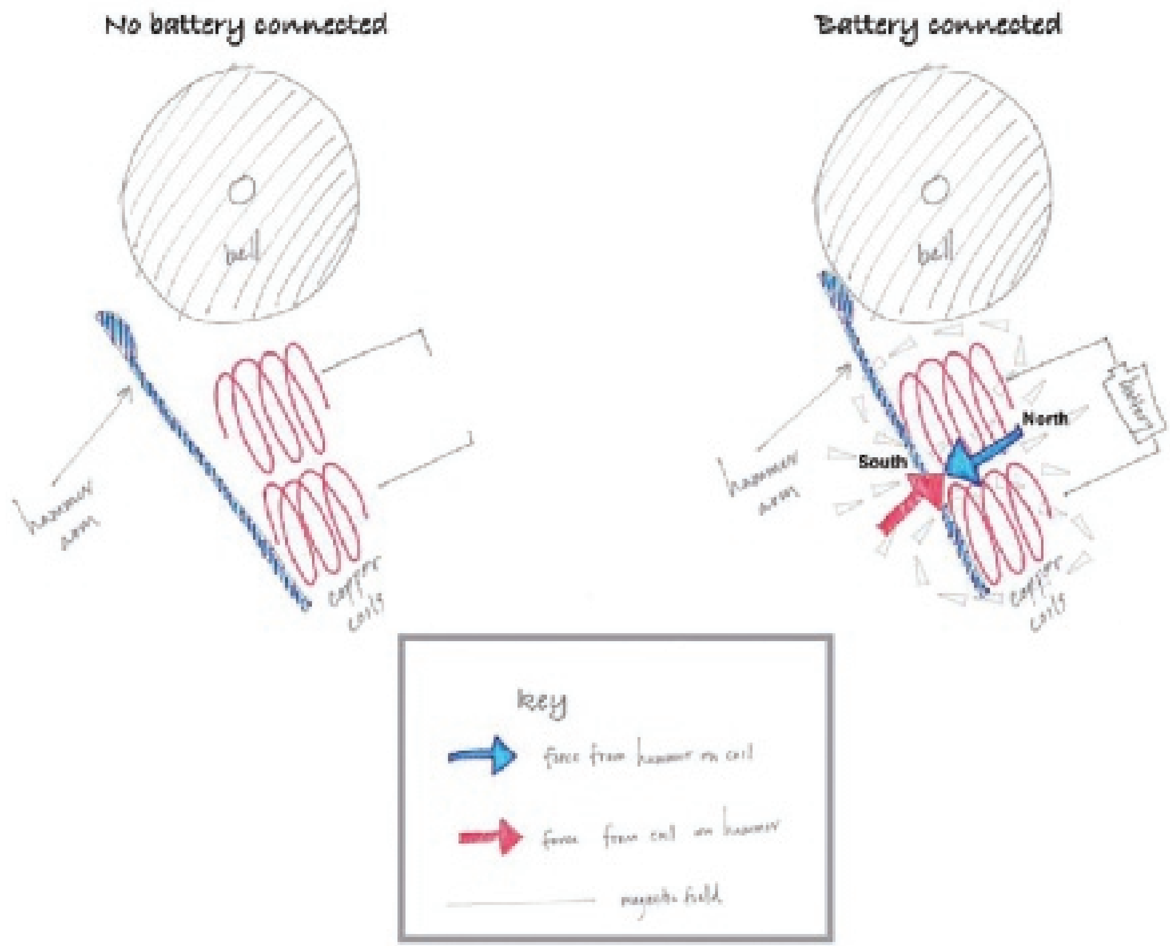
+ Attractive forces are shown.

+ Student draws a force pair with equal and opposite forces.

+ A force is on the hammer.

+ Forces are clearly drawn and labeled.

Ideal student response(s)



If you have time, consider using the following questions to help students make connections to earlier units.

3. **Extension from 8.1 Broken Things**

   The doorbell is a designed system. Its purpose is to produce sound. Think back to the Broken Things Unit to answer the following questions:

   What happens to the bell when the hammer strikes it? What can you say about the contact forces and deformation happening between both objects during this collision?

   + When the hammer strikes the bell, each object applies a contact force on the other object.

   + The force on the bell from the hammer causes the bell to deform.

4. **Extension from 8.2 Sound Waves**

   Think back to the Sound Waves Unit and answer the following questions:

   a. What happens to the bell as the hammer strikes it (and after it strikes it) that **causes** that collision to produce a sound?

   b. In a typical doorbell, the bell that produces the sound is located inside the house. How does a person in the house hear the sound coming from the bell? How does the sound move across the space between the bell and their ears?

   a:

   + After the bell is deformed, it springs back past its original shape; this elastic behavior causes it to vibrate, or move back and forth.

   b:

   + Repeated cycles of vibration move into and away from air around it, producing compressed bands of air molecules.

   + These compressed bands of air molecules collide with neighboring air molecules, transferring energy to them.

   + When these compression bands reach our ears they push on structures in our ears that deform in response and allow us to hear that sound.

LESSON 8: TEACHER REFERENCE

Electricity extension opportunity

Electricity extension opportunity

Lessons 8-12 include a set of Additional Guidance callout boxes designed to provide a coherent enrichment experience for students who are interested in learning more about electricity or who have met and exceeded the performance expectations. These might also be helpful if your state has standards in addition to those laid out in the NGSS related to electricity and circuits. Look for Additional Guidance with the heading "Electricity extension opportunity" to find optional enrichment support over the next four lessons. There may also be optional handouts associated with these Additional Guidance boxes.

Lesson 8

In this lesson, students learn about the role of electric current in producing an electromagnet that can switch polarity. Students do not learn what *electric current* is. For students who want to learn more, *What is electric current?* offers an extension opportunity that you can assign as home learning. In this handout, students learn that electric current is the movement of charged particles called *electrons*. They also learn that electrons can move very slowly in the wire, much more slowly than electrical energy is transferring. Finally, students are directed to a PhET computer interactive where they can apply what they have learned to build a circuit that powers a lightbulb. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 9

Included as an optional handout in this lesson is a reading about electricity for students who want to go deeper. The reading is not included in the student materials. This reading describes the parallels between forces at a distance due to electricity and forces at a distance due to magnetism. It describes how we can use electric fields to explain the energy transferred by electricity in circuits, just as we use magnetic fields to explain energy transferred by magnets. The reading also explains what voltage is and how that relates to the changing current that we discovered in Lesson 8. This is a level 9 reading, so consider using a close-reading protocol like the one in Lesson 8 to scaffold the reading.

Finally, students are directed to a PhET computer interactive to test out some of their ideas about voltage and electric shocks. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 10

In Lesson 10, students will plan and carry out an experiment in small groups. For students who are following the extension path, this represents an opportunity for them to plan an experiment individually in the context of electricity. Consider asking these students to design an additional experiment as home learning to answer the following question: *When we change the distance between two charged objects, do the electrical forces get stronger?* These students should turn in

- a hypothesis,
- a set of procedures,
- a list of materials, and
- a prediction about the results.

Lesson 11

For students following this path, ask them to include what they have learned about electron motion in a wire in the cause-effect chain in *Cause-Effect Chain*. Remind them that they can modify the handout to add more boxes to the chain of cause and effect if needed.

Lesson 12

Included as an optional handout in this lesson is a transfer task with ideas students have developed about electricity. The task asks students to use a short reading about microphones to reconstruct the series of cause-effect relationships that make the microphone work and then model a microphone in a diagram.

Name: ____________________ Date: ____________________

LESSON 9: RUBRIC

Rubric for Model in Lesson 9

Components The model clearly represents or describes:	**Category**			**Feedback**
	Missing	Developing	Mastered	
A coil of wire connected to a music player				
A permanent magnet that is not touching the coil of wire				
A speaker cone that is attached to the coil				
Invisible Factors The model clearly represents or describes:	**Category**			**Feedback**
	Missing	Developing	Mastered	
A magnetic field with an indication of direction (i.e., pointers indicating the way a compass needle would be aligned at that point in space)				
Polarity of the magnet such that the magnetic field is pointing out of the south pole of the magnet and into the north pole				
Force pairs that are equal and opposite, labeled to indicate that the force on the permanent magnet is due to the electromagnet and vice versa				
Interactions (cause-effect relationships) The model clearly represents or describes:	**Category**			**Feedback**
	Missing	Developing	Mastered	
Energy transfer by magnetic forces out of the magnetic field <u>causes</u> the coil (and attached speaker cone) to move				
Electric current coming from the music player <u>causes</u> the coil of wire to become a magnet (electromagnet)				
Changing current coming from the music player <u>causes</u> the forces to change, causing the patterns of motion that create the sound we hear				

The Identify and Interpret (I^2) Strategy - Teacher Guide

Students can become overwhelmed when they try to interpret graphs, figures, or data tables. The Identify and Interpret (I^2) strategy is a way to help students make sense of the information by breaking it down into smaller parts.

In the I^2 strategy, students first identify changes, trends, or differences. They draw an arrow to each observation and then write a “What I see” (WIS) comment. These comments should simply be what the student observes, such as a positive slope on a graph or increasing numbers in a data table. After students have made all their observations and written their WIS comments, they should interpret the meanings of their observations by writing a “What it means” (WIM) comment for each. Once students have mastered WIS and WIM comments, ask them to create a caption for the graph, figure, or table. A caption is a summary of all the information and helps show students’ understanding.

To use the I^2 strategy, you should have students place the graph, figure, or table that they are interpreting into their science notebooks. They should then draw the arrows and write their comments on and around the image. This helps them make the connections between the graphical information and their ideas. They should write the caption on the same page to help remind them of the interpretation.

Help students with page management as you use the strategy. Remind them to leave plenty of room around the graph, figure, or table so they can write their WIS and WIM comments. Also make sure they have room below the graph or figure to write their captions.

When you first begin using this strategy, model it for students. They can benefit greatly from watching you do a “think-aloud” as you complete the strategy on a graph, figure, or table. In the beginning, ask students to complete only the WIS and WIM comments without writing a caption. They will likely need help understanding what they should be looking for on the graph. Some students do not add enough arrows and WIS comments to interpret all the information. Other students try to add as many arrows and WIS comments as possible. These students soon find that they cannot interpret the meaning of some of their WIS comments. For example, if they identify that a graph is printed in black ink, they will discover that they cannot assign meaning to this WIS comment. This stage helps students begin to filter their numerous observations and identify only those that are significant to the graph, figure, or table.

Once students have become proficient at writing WIS and WIM comments, ask them to add a caption. Some students will find it repetitive since they are joining the WIS and WIM comments to create most of their captions; however, help them realize that the ability to create a coherent paragraph that interprets all parts of a graph, figure, or table is an important skill in science and other subjects. Later, when students have had a great deal of practice with this strategy, the ultimate goal should be for them to write a caption without having to list their WIS and WIM comments. Eventually, these comments become a habit of mind, and students should be able to notice all the pieces of a graph or figure to come up with a complete interpretation. Developing these habits of mind to identify and interpret data in many forms is a skill that will benefit students in all subjects, in their jobs as they get older, and in becoming scientifically literate citizens.

Summative Assessment

Electromagnetic Inventions

1. Choose an electromagnet application from the list that the class brainstormed or from a new idea you have. It can be anything that uses an electromagnet. Identify and describe the device you chose.

2. Draw a **model** that explains how your device works. Make sure your model includes forces acting at a distance.

3. Describe the cause-and-effect relationships that allow your device to work and explain how they make your device work.

Design an Investigation

An engineer suggests that copper might not be the best material for transferring energy into the electromagnet in your device. She suggests trying silver wire instead.

4. Write a hypothesis that describes a cause-and-effect relationship in the electromagnet that you would expect to see if the engineer is correct.

	Explanation about which material is best		**Change you will make to the system to test this explanation (cause)**		**Effect on the system you expect to see**
If		**then when we**		**we will observe**	

5. You need to decide if you are going to use silver in your device. How would you design an investigation to test which metal is better for your device, copper or silver? Answer the questions below to describe your investigation.

   a. Write an investigation question using cause-effect sentence framing that describes what you are testing.

   b. What are your variables?

      Independent: ______________________________

      Dependent: ______________________________

      Constant(s): ______________________________

   c. Describe the procedure you would use to do your investigation.

d. The engineer claimed that the new metal coil would improve the function of your device. What pattern would you expect to see in your data that would support that claim? Use any combination of drawings and words to describe these patterns.

Summative Assessment

Electromagnetic Inventions

1. Choose an electromagnet application from the list that the class brainstormed or from a new idea you have. It can be anything that uses an electromagnet. Identify and describe the device you chose.

   + Description includes an application of an electromagnet.

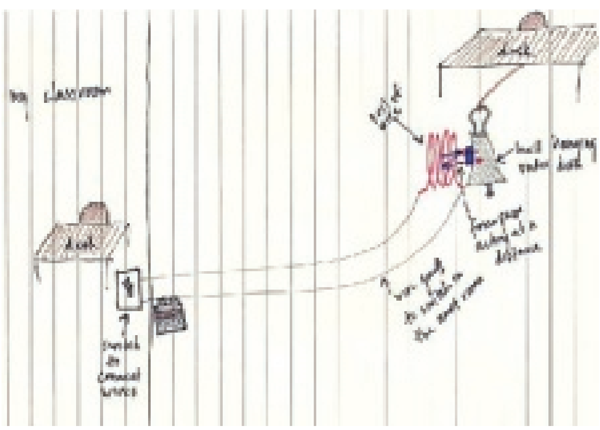
   Example A: I want to make a communication device to alert my friends in the classroom down the hall. It would have a switch in this classroom that I could turn on and off by pressing a button. Then it would have a wire going to the other classroom with a coil at the end. When I press the button, the coil would turn into an electromagnet and there would be a magnet that it pulls on that is connected to a bell. When it pulls on the magnet, the bell rings.

   Example B: I want to make a magnet that can pick up cars and move them in a parking garage so that people can double park and we can fit more cars in. It would be a giant electromagnet with a bunch of coils and lots of current so that the force is bigger.

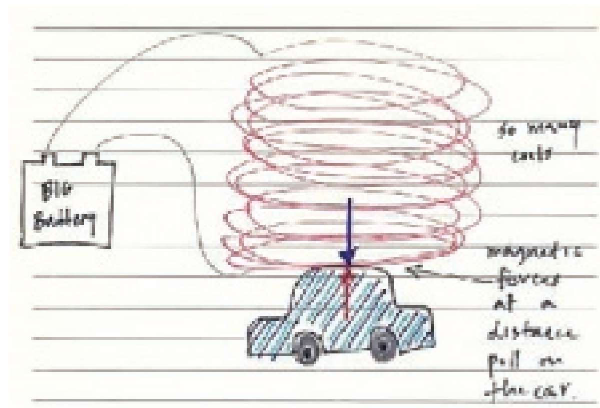
2. Draw a **model** that explains how your device works. Make sure your model includes forces acting at a distance.

   Scoring guidance for this question is in question 3.

   Example A:



   Example B:



3. Describe the cause-and-effect relationships that allow your device to work and explain how they make your device work.

   Score questions 2 and 3 together to give students multiple ways to show what they know. Score based on science ideas and practices or crosscutting concepts, not on whether you think the device will actually work. The responses should include these details:

   + describes current moving through the wire (either in words or drawn is fine)

   + describes a magnetic field being produced (or changed if there is a permanent magnet in the system) when current is running through the wire

   + connects the magnetic field to the functioning of their device

   + describes how the parts of the device interact to make the device work

   Example A: When I press the button, electric current goes through the wire and the coil of wire produces a magnetic field. Forces in the magnetic field between the permanent magnet and the electromagnet will pull on the magnet which is attached to the bell and make it ring.

Example B: When we turn on the electromagnet by connecting it to a battery, electric current goes through the wire and the coil of wire produces a magnetic field. Forces in the magnetic field between the car and the electromagnet pull on the car and are able to pick up and move the car.

Design an Investigation

An engineer suggests that copper might not be the best material for transferring energy into the electromagnet in your device. She suggests trying silver wire instead.

4. Write a hypothesis that describes a cause-and-effect relationship in the electromagnet that you would expect to see if the engineer is correct.

	Explanation about which material is best		**Change you will make to the system to test this explanation (cause)**		**Effect on the system you expect to see**
If	+ silver is the best material for my device (because it transfers energy better)	**then when we**	+ change the material of the coil to silver	**we will observe**	+ the electromagnet producing stronger (or weaker) force pairs inside the device (or transferring more or less energy) (or make things move more or less)

5. You need to decide if you are going to use silver in your device. How would you design an investigation to test which metal is better for your device, copper or silver? Answer the questions below to describe your investigation.
   a. Write an investigation question using cause-effect sentence framing that describes what you are testing.

      + uses cause-effect sentence framing in the question, for example:

      When I use silver instead of copper in the electromagnet, will I observe stronger forces in the system?

      + writes an investigation question that is testable and relevant to the investigation, for example:

      Which metal produces the weakest forces between the electromagnet it is in and a permanent magnet?

      Which metal allows more current to go through it, silver or copper?

      Which metal transfers more energy into the magnetic field, silver or copper?

      Which metal picks up the car with more force, silver or copper?

      Which metal in the electromagnet makes the train go faster, silver or copper?

   b. What are your variables?

      Independent: ______________________

      + metal type (or silver vs copper)

      Dependent: ______________________

      + describes a relevant, measurable variable, for example: strength of forces between the magnet and the electromagnet (or energy transferred into the electromagnet or amount of movement observed in the electromagnet [number on the scale, speed of the electromagnet or magnet, sound made in a collision])

      Constant(s): ______________________

      + describes what they will keep constant in the investigation, for example: distance between the coil and magnet, number of coils, number of batteries hooked up to the coil

   c. Describe the procedure you would use to do your investigation.

      Describes how they would measure:

      + the independent and

      + dependent variables that they identified

      + Describes how to ensure holding at least one variable constant (does not need to be explicit, e.g., specific number of coils is noted or specific distance from scale is noted)

+ Describes how to collect and record the data

+ Description is in a coherent, easy to follow sequence

Example:

1. I would make a coiled copper wire for a certain number of loops (e.g., my control would be 50 loops in the coils).
2. I would set this up for a fixed distance (1 cm) from the scale with the coils turned parallel to the magnet on the scale (see diagram).
3. After zeroing the scale and then hooking up a battery to the coil, I would record the force measured on the scale.
4. Now I would repeat the experiment with silver instead of copper wire.
5. I would repeat steps 2 and 3 with this new material.

d. The engineer claimed that the new metal coil would improve the function of your device. What pattern would you expect to see in your data that would support that claim? Use any combination of drawings and words to describe these patterns.

+ The forces for silver are higher than the forces with copper (or the energy transfer for silver or a proxy for forces or energy transfer such as sound in a collision, number on a spring scale or electronic balance, number of cracks in a graham cracker, amount of squish in a clay ball or bend in a wooden stirrer, speed of the electromagnet)

+ Links these data to the claim that silver will make the device work better

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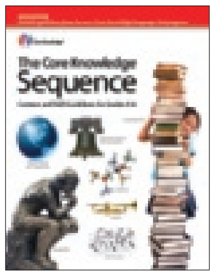

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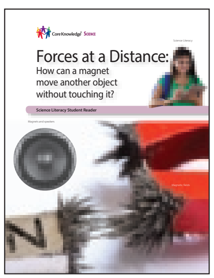
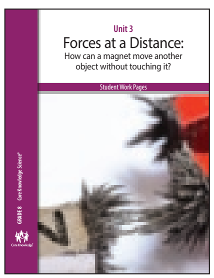
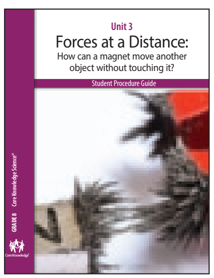
The *Core Knowledge Sequence* is a detailed guide to specific content and skills to be taught in Grades K–8 in language arts, history, geography, mathematics, science, and the fine arts. In the domains of science, including Earth and space, physical, and life sciences, the *Core Knowledge Sequence* outlines topics that build systematically grade by grade to support student learning progressions coherently and comprehensively over time.







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In general, the content and presentation are appropriate for students in middle school, Grades 6–8. For teachers and schools following the *Core Knowledge Sequence*, these books are intended for Grade 8 and are part of a series of **Core Knowledge SCIENCE** units of study.

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