AmplifyScience

Magnetic Fields:

Launching a Spacecraft

Investigation Notebook with Article Compilation

These materials are based upon work partially supported by the National Science Foundation under grant numbers DRL-1119584, DRL-1417939, ESI-0242733, ESI-0628272, ESI-0822119. The Federal Government has certain rights in this material. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

These materials are based upon work partially supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A130610 to The Regents of the University of California. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

Amplify.
55 Washington Street, Suite 800
Brooklyn, NY 11201
1-800-823-1969
www.amplify.com

Magnetic Fields: Launching a Spacecraft
ISBN: 978-1-947002-86-9
AMP.NA18

Magnetic Fields:

Launching a Spacecraft

Investigation Notebook

Table of Contents

Table of Contents (continued)

Table of Contents (continued)

Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: ______________________________ Date: ____________________

Magnetic Fields: Launching a Spacecraft
Unit Overview

The exploration of space is important, exciting, and costly. What if the cost of launching spacecraft into space could be dramatically reduced? Could magnets be the secret to cheaper space travel? In this unit, you'll learn about a model magnetic spacecraft launcher that is being used to develop less expensive ways to explore space. You will investigate how the magnetic spacecraft launcher works and uncover why a recent model launcher test may have gone wrong.

Name: ______________________ Date: ______________

Chapter 1: Modeling Magnetic Force
Chapter Overview

You have been tasked with helping the Universal Space Agency investigate unexpected results from tests of a model magnetic spacecraft launcher. To begin your investigation, you must first learn how a magnetic launcher works by studying systems of magnets. Understanding magnetic force will help you evaluate the surprising results of the test launches.

Name: ______________________________ Date: ____________________

Lesson 1.2: Introducing the Magnetic Spacecraft

Welcome to your new unit on magnetic fields! You are about to take on the role of student physicists. Today, you will learn about the Universal Space Agency's magnetic spacecraft launcher and start working together to investigate why the agency's new model spacecraft is launching at a much higher speed than they had expected. You will begin by working with magnets and exploring a digital Simulation to figure out how magnets move other objects. The Universal Space Agency is counting on you, so let's get to it!

Unit Question

- Why do magnets move objects in different ways?

Chapter 1 Question

- How can the launcher make the model spacecraft move without touching it?

Vocabulary

- attract
- repel

Digital Tools

- *Magnetic Fields* Simulation

Name: ______________________ Date: ______________

Warm-Up

How can a magnet launch something?

In this unit, you will learn about why magnets move objects in different ways, including launching an object into space at different speeds.

Record your initial thinking about the questions below.

How do you think a magnet can cause something to move?

____

____

____

____

What are the different ways a magnet can move an object?

____

____

____

____

Name: ______________________________ Date: ____________________

Introducing the Magnetic Spacecraft

As you watch the video, *Troubleshooting a Magnetic Launcher,* consider the questions below. After watching the video, take a few minutes to discuss the questions with your partner.

- How do you think the launcher can make the spacecraft move without touching it?
- Why do you think the spacecraft's speed was different on the Monday, Tuesday, and Wednesday launches?

Name: ______________________________ Date: ________________

Exploring and Simulating Magnets

Investigation Question: *How do magnets move objects?*

1. Observe and gather evidence during each activity to help you answer the Investigation Question.
2. Record your observations below.

Observations from *Exploring Magnets* activity	Observations from *Simulating Magnets* activity

Name: ______________________________ Date: ____________________

Homework: Rules About Magnets

Decide whether you **agree** or **disagree** with each claim below.

1. Magnets attract some metals. (check one)

   ☐ agree

   ☐ disagree

2. Magnets repel wood. (check one)

   ☐ agree

   ☐ disagree

3. A magnet must be touching an object to repel it. (check one)

   ☐ agree

   ☐ disagree

4. Magnets can move other objects from a distance. (check one)

   ☐ agree

   ☐ disagree

5. Magnets can attract or repel other magnets. (check one)

   ☐ agree

   ☐ disagree

Name: ______________________ Date: ______________

Homework: Reading "Meet a Scientist Who Studied Magnets"

How do scientists know what they know about magnets? To learn more about a scientist who overcame many challenges to make new discoveries about magnets, read and annotate the "Meet a Scientist Who Studied Magnets" article. Then, answer the question below.

What is one interesting thing you learned from this article?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ______________

Lesson 1.3: Evaluating Magnetic Force Evidence

Good day, student physicists! In this lesson, you will be evaluating evidence another student physicist has collected to decide if you agree with his claim. How can you decide whether or not you can trust his data? What does the data tell you about whether a magnetic force will cause magnets to attract each other, repel each other, or both? How can a visual model help you communicate this information to other people? Let's find out!

Unit Question

- Why do magnets move objects in different ways?

Chapter 1 Question

- How can the launcher make the model spacecraft move without touching it?

Key Concepts

- A magnetic force can attract or repel an object at a distance.

Vocabulary

- attract
- isolate
- magnetic pole
- model
- refute
- repel
- system
- variable

Digital Tools

- *Magnetic Fields* Simulation

Name: ______________________ Date: ______________

Warm-Up

Evidence About Magnets

Barry, another student physicist, ran some tests on how magnets affect other magnets. Based on his evidence, Barry has claimed:

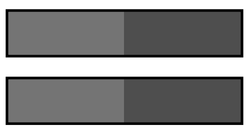
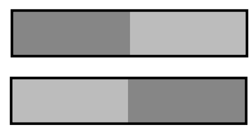
Strong magnets repel and weak magnets attract.

Review Barry's evidence and then answer the questions.

Barry's Evidence

strong magnet

weak magnet

	Test 1	**Test 2**
Position of magnets before they were released		
Results when the magnets were released	moved **away** from each other	moved **toward** each other

Do you agree with Barry's claim? (check one)

- ☐ yes
- ☐ no

Do you think his evidence is strong? Why or why not?

____

____

____

____

Name: ______________________________ Date: ____________________

Evaluating Evidence

1. Evaluate the evidence on the Evidence Cards that the other student physicists produced to refute Barry's claims.
   - What is different and what is similar about the magnets in the two tests?
   - How many variables were changed for the second test?
2. Based on your evaluation, place the Evidence Cards on the Evidence Gradient. Remember that evidence is stronger when the variable being tested is isolated, which means only one variable is changed at a time.
3. After you evaluate the evidence, complete the poll:

To help show Barry that his claim is inaccurate, select the strongest evidence card to share with him. (check one)

- ☐ Evidence Card A
- ☐ Evidence Card B
- ☐ Evidence Card C
- ☐ Evidence Card D
- ☐ Evidence Card E

Name: ______________________________ Date: ____________________

Modeling Systems of Magnets

Complete the Modeling Tool activity: Attracting and Repelling Magnets on the next page.

Goal: Create two models. In one model, show two magnets that will **attract.** In the other model, show two magnets that will **repel.** Use the symbols shown in the Key in your models.

Do:

- In the left panel, draw two magnets positioned so that a magnetic force will cause motion.
- In the right panel, show what would happen to the magnets after you let them move freely.

Name: ______________________ Date: ______________

Modeling Systems of Magnets (continued)

Attracting and Repelling Magnets Modeling Tool

	held in place	after release
Attracting magnets		
Repelling magnets		

Key

direction of motion

magnet

magnetic field line

Name: ______________________________ Date: ______________________

Homework: Magnetic Launchers and Catchers

How can you build a “magnet catcher” or a “magnet launcher”?

Use the Simulation to complete the tasks below. Draw and label your successful setup for each task.

1. Launch the *Magnetic Fields* Sim. Place a weak magnet horizontally at the bottom of the screen. Set up a locked magnet so it will attract the weak magnet at a distance. If necessary, test and revise your setup until you find a successful solution.

Below, sketch and label the setup for your successful “magnet catcher.”

2. Place a weak magnet vertically near the left side of the screen. Set up a locked magnet so it will repel the weak magnet off the right side of the screen. If necessary, test and revise your setup until you find a successful solution.

Below, sketch and label the setup for your successful “magnet launcher.”

Name: ______________________________ Date: ________________

Lesson 1.4: "Earth's Geomagnetism"

A magnetic force can attract or repel—and may do both things at the same time! When does this happen? Why does this happen? How is this related to the fact that a compass needle will always rotate to point north, no matter where you are on Earth? Today, you will read about the magnetic field that surrounds Earth and learn how scientists visualize the mysterious magnetic force produced by this magnetic field.

Unit Question

- Why do magnets move objects in different ways?

Chapter 1 Question

- How can the launcher make the model spacecraft move without touching it?

Key Concepts

- A magnetic force can attract or repel an object at a distance.
- In a system of magnets, there is a repelling force between like poles and an attracting force between opposite poles.

Vocabulary

- attract
- isolate
- magnetic field
- magnetic field line
- magnetic pole
- model
- repel

Name: ______________________ Date: ______________

Warm-Up

In the center of a compass, there is a small magnet called a needle that points north. When a compass is turned, the needle will rotate until it points north again.

Why do you think a compass needle always points north? (Write your initial ideas. It is okay if you are unsure about them.)

____

____

____

____

____

____

Name: ______________________ Date: ______________

Reading “Earth’s Geomagnetism”

1. Read and annotate the article “Earth’s Geomagnetism.”
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________ Date: ______________

Lesson 1.5: Investigating Magnetic Field Lines

Welcome back, student physicists! The Universal Space Agency needs you to analyze some new data, in the form of diagrams, about the model spacecraft launcher tests. Before you can tackle this assignment, you will need to understand how to use scientific models to predict whether magnets will attract each other, repel each other, or both. In this lesson, you will return to the "Earth's Geomagnetism" article and use the digital Simulation to investigate how scientists model magnetic field lines.

Unit Question

- Why do magnets move objects in different ways?

Chapter 1 Question

- How can the launcher make the model spacecraft move without touching it?

Key Concepts

- A magnetic force can attract or repel an object at a distance.
- In a system of magnets, there is a repelling force between like poles and an attracting force between opposite poles.

Vocabulary

- attract
- magnetic field
- magnetic field line
- magnetic pole
- model
- repel
- system

Digital Tools

- *Magnetic Fields* Simulation

Name: ____________________ Date: ____________

Warm-Up

Does a compass always point north? Use the *Magnetic Fields* Simulation to help you determine how a compass needle responds to a magnetic field, and what direction it will point in at different locations around a magnet.

1. In the Sim, place a bar magnet in the center of the screen.
2. Press the Field Lines toggle at the top of the screen to display field lines.
3. Press RUN, then ANALYZE at the top of the screen.
4. Select the COMPASS tool and drag it onto the screen.
5. Move the compass to different locations around the magnet and observe the direction of the compass needle at each location.

What happens to the compass needle as you move the compass around? (check one)

- ☐ The compass needle always points north.
- ☐ The compass needle points in random directions.
- ☐ The compass needle follows the pattern of magnetic field lines.
- ☐ The compass needle's north pole always points to the north pole of the magnet.

Name: ______________________ Date: ______________

Rereading "Earth's Geomagnetism"

Reread the second and third paragraphs in the "Earth's Geomagnetism" article. Then, answer the question.

How are magnetic field line models helpful?

____

____

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________ Date: ______________

Exploring Field Lines

How can you tell whether two magnets will attract each other, repel each other, or do both?

Use the *Magnetic Fields* Simulation to help you answer the questions. Sketch what you see in the Sim to support your answers.

- Turn on Field Lines by pressing the toggle at the top of the screen, then drag two bar magnets onto the screen.
- Try arranging the magnets in several different ways and observe the magnetic field lines as the magnets attract and repel each other.
- Press RUN to observe how the magnets interact.
- Press ANALYZE to review and closely examine field lines.

Part 1: Repelling

What do magnetic field lines look like when two magnets repel? (check one)

- ☐ Most field lines connect a pole of one magnet to a pole of the other magnet.
- ☐ All field lines connect one pole of a magnet to the opposite pole of that same magnet.

Sketch a magnetic field line pattern that represents a repelling force.

Name: ____________________ Date: ____________

Exploring Field Lines (continued)

Part 2: Attracting

What do magnetic field lines look like when two magnets attract? (check one)

- ☐ Most field lines connect one pole of one magnet to the opposite pole of the other magnet.
- ☐ All field lines connect one pole of a magnet to the other pole of that same magnet.

Sketch a magnetic field line pattern that represents an attracting force.

Part 3: Repelling and Attracting

Sketch a magnetic field line pattern that represents both a repelling and an attracting force.

Name: ______________________________ Date: ____________________

Modeling Magnetic Field Lines

Turn back to your Modeling Tool activity: Attracting and Repelling Magnets on page 15.

Goal: Revise your previous models by adding magnetic field lines to each system of magnets.

Do:

- Make any necessary changes to your previous model to show how your thinking has changed.
- Draw magnetic field lines around the magnets.

Name: ______________________________ Date: ________________

Homework: Reading “Painting with Static Electricity”

You have learned a lot about magnetic fields. To learn about a different type of field, read and annotate the “Painting with Static Electricity” article. Then, answer the questions below.

1. What are some ways that electric fields are similar to magnetic fields.

____

____

____

____

2. What is one way that an electric field is different from a magnetic field?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ____________________

Lesson 1.6: Analyzing Field Line Data

Hello, student physicists! Now you have a better understanding of magnetic force and magnetic field lines, and you're just in time: We have finally received the magnetic field line data Dr. Shapiro promised us from the Universal Space Agency. Does the evidence support or go against the claim that the model spacecraft and launcher magnets were misaligned on Tuesday? Dr. Shapiro is eager to read your analysis, so let's get started!

Unit Question

- Why do magnets move objects in different ways?

Chapter 1 Question

- How can the launcher make the model spacecraft move without touching it?

Key Concepts

- A magnetic force can attract or repel an object at a distance.
- In a system of magnets, there is a repelling force between like poles and an attracting force between opposite poles.
- The pattern of magnetic field lines around attracting magnets is different from the pattern of magnetic field lines around repelling magnets.

Vocabulary

- attract
- magnetic field
- magnetic field line
- magnetic pole
- model
- refute
- repel
- system

Name: ______________________________ Date: ____________________

Warm-Up

Part 1: Predicting Magnet Motion

Complete the Modeling Tool activity: Predicting Magnet Motion on the next page.

Goal: Use the magnetic field lines to determine the orientation of the magnets in each diagram and to predict how the magnets will move.

Do:

- Label the rest of the poles in each diagram.
- In the “after release” panel, show how the magnets will move when they are released.

Part 2: Discussing Magnetic Field Line Models

Share the models you just completed with a partner. Discuss the following questions:

- How did you identify where the poles of each magnet should be?
- How did you decide what the position of the magnets would be after they were released?

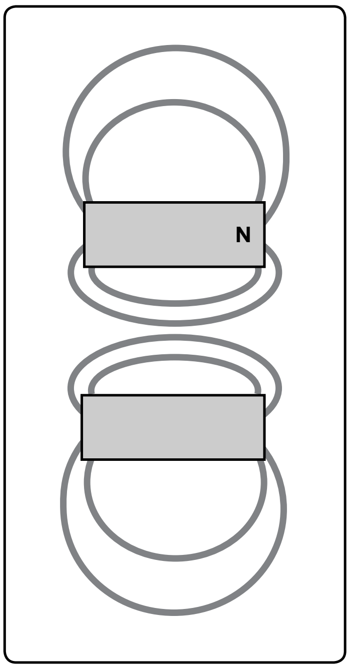
Name: ______________________________ Date: ________________

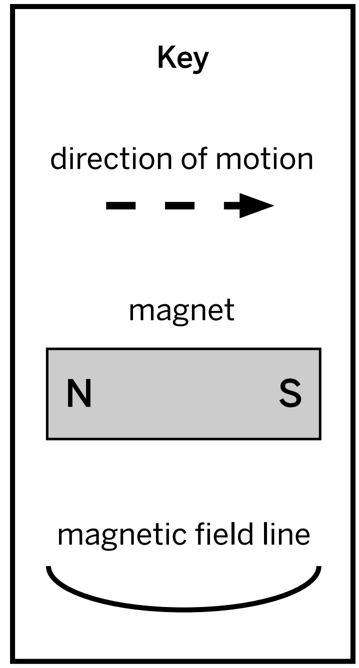
Modeling Tool: Predicting Magnet Motion

Use the magnetic field lines to determine which way the north and south poles of the magnets are facing in each diagram, then predict how the magnets will move. Use the symbols shown in the Key in your models.

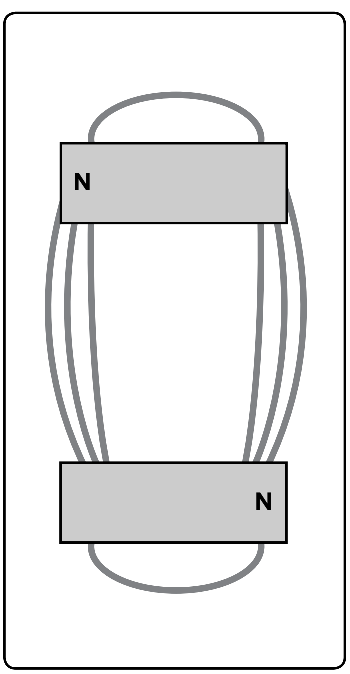
held in place | **after release**

Model A





Model B

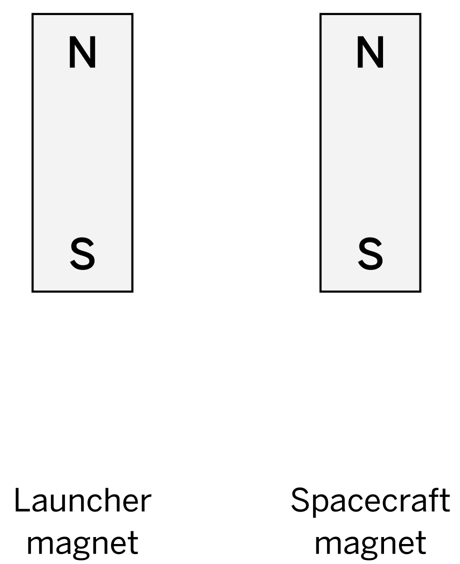


Name: ______________________ Date: ______________

Launcher Alignment

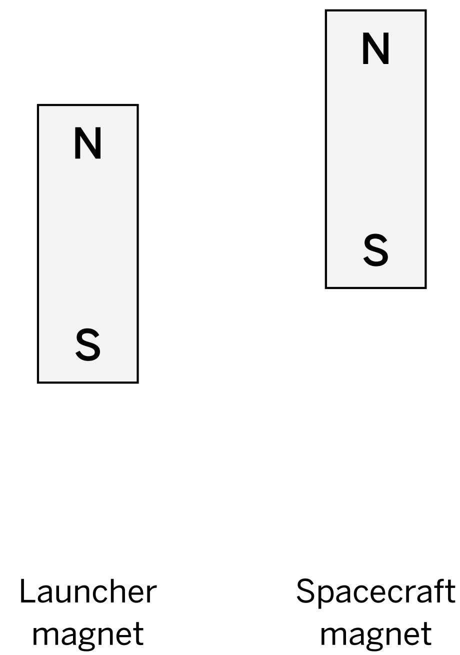
Modeling Magnetic Forces for an Aligned Launcher

Draw the field lines for this aligned magnet system.



Modeling Magnetic Forces for an Misaligned Launcher

Draw the field lines for this misaligned magnet system.



Name: ______________________________ Date: ________________

Evaluating a Claim

Dr. Shapiro has asked you to analyze the Magnetic Field Line diagrams and determine whether the data supports the claim that the magnets in the launcher were misaligned during the Tuesday test launch, causing it to be slower than expected.

Explain how the magnetic field line data supports or refutes the claim that the launcher and spacecraft magnets were misaligned in the Tuesday launch. Refer to the words and phrases below to help you write your response.

Word and Phrase Bank

attract	refute	because	therefore
magnetic field lines	repel	if . . ., then . . .	poles
system	system	since	

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

Name: ______________________________ Date: ________________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the model spacecraft went so much faster than expected on Wednesday?

1. I understand how the launcher can make the model spacecraft move without touching it. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

2. I understand where the energy to launch the model spacecraft came from. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

3. I understand how force caused different amounts of potential energy to be stored in the launcher system. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

Name: ______________________________ Date: ______________

Homework: Check Your Understanding (continued)

4. I understand how potential and kinetic energy changed during the spacecraft launches. (check one).

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

5. What do you still wonder about the magnetic spacecraft launcher?

____

____

____

____

____

____

Name: ______________________ Date: ______________

Chapter 2: Investigating Potential Energy
Chapter Overview

Great work on eliminating Claim 1! Now that we know the magnets were not misaligned, we will continue to investigate why the model spacecraft went so much faster than expected in the Wednesday launch. In this chapter, you will investigate the energy in magnetic fields by exploring how magnets get kinetic energy.

Name: ______________________________ Date: ____________________

Lesson 2.1: The Potential for Speed

Welcome back, student physicists! Great work eliminating the claim that the spacecraft and launcher magnets were misaligned! You will now think about the energy in the system of magnets. In this lesson, you will read an article about an extreme sport to learn how a system can transfer energy to an object (or human) and cause a change in speed. Where is the kinetic energy coming from? How does the kinetic energy get there? What in the world is powerbocking? Let's find out!

Unit Question

- Why do magnets move objects in different ways?

Chapter 2 Question

- Where did the energy to launch the model spacecraft come from?

Vocabulary

- attract
- energy
- kinetic energy
- magnetic field
- potential energy
- repel
- system

Digital Tools

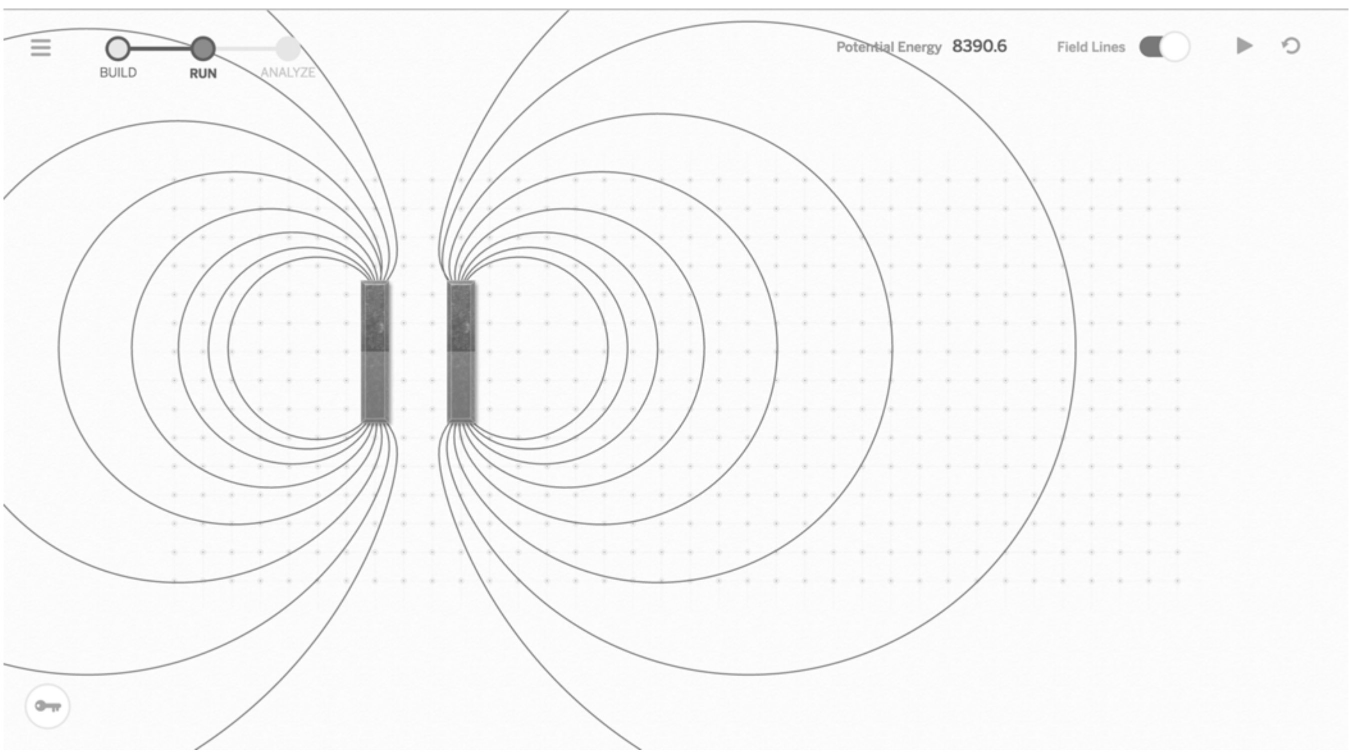
- *Magnetic Fields* Simulation
- *Harnessing Human Energy* Simulation

Name: ________________________________ Date: ____________________

Warm-Up

How does the energy in a system of magnets change when two magnets repel and move away from each other?

1. In the *Magnetic Fields* Simulation, set up two magnets so that they will move directly away from each other in a straight line.
2. Press RUN to observe the motion of the magnets, then press ANALYZE.
3. Look at the energy graph to see how the amounts of each type of energy in the system change when the magnets move.
4. Circle the bold phrases in the sentence below that reflect your observations.



When the magnets started moving, the amount of (**kinetic energy** / **potential energy** / **thermal energy**) went down and the amount of (**kinetic energy** / **potential energy** / **thermal energy**) went up.

Name: ______________________________ Date: ________________

Reading *The Potential for Speed*

1. Read and annotate an article from the article set *The Potential for Speed*
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ______________

Homework: Simulating Energy Transfers

Use the *Harnessing Human Energy* Simulation to find examples of potential and kinetic energy. Create a system that uses potential and kinetic energy. Name the parts of your system, then answer the questions.

Tips for Using This Simulation

- Press the left and right arrow buttons in the SELECT ENERGY SOURCE box to choose a type of energy.
- Drag devices from the toolbar into the DRAG DEVICES HERE box.
- Press RUN to test your device and observe the types of energy it uses.
- If the blue TRANSFER button appears, press it to see how energy is transferred.
- Press ANALYZE and use the slider to play the test again.

List the items you used in your system, starting with the energy source.

____

____

____

____

____

____

What part (or parts) of your system store potential energy?

____

What part (or parts) of your system use kinetic energy?

____

Name: ______________________ Date: ______________

Lesson 2.2: Exploring Potential and Kinetic Energy

Can reading about how a person gets kinetic energy when they participate in an extreme sport help you figure out how a magnet gets kinetic energy when it is moved by another magnet? Where does the kinetic energy come from? Let's find some answers!

Unit Question

- Why do magnets move objects in different ways?

Chapter 2 Question

- Where did the energy to launch the model spacecraft come from?

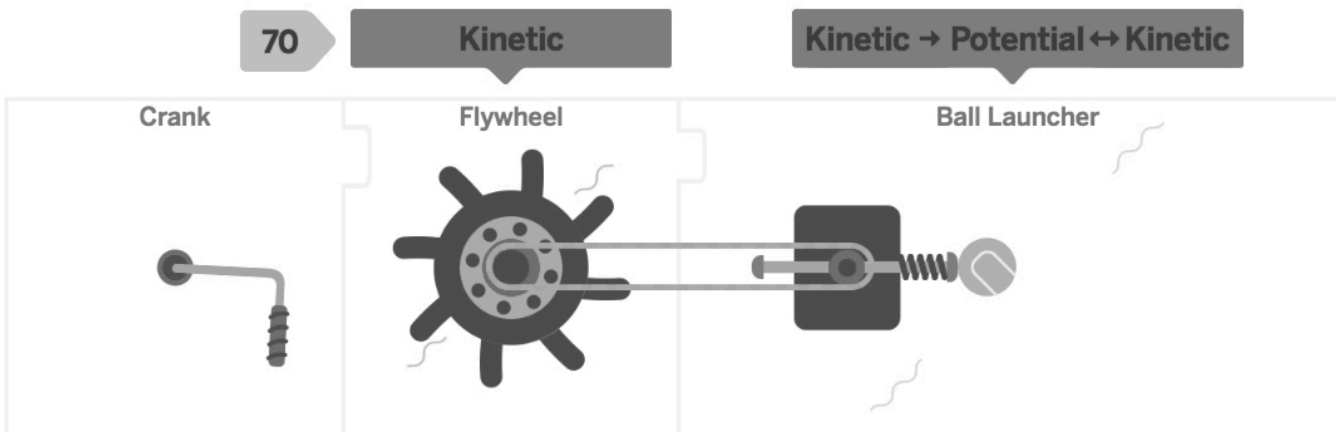
Vocabulary

- attract
- convert
- energy
- kinetic energy
- magnetic field
- potential energy
- repel
- system
- transfer

Name: ______________________ Date: ______________

Warm-Up

This flywheel and ball launcher powered by a hand crank is one possible system that you could have created in your homework assignment.



What part (or parts) of this system store potential energy?

____

What part (or parts) of this system have kinetic energy?

____

If an object has kinetic energy, what must it be doing?

____

____

Name: ______________________________ Date: ________________

Sharing Ideas About Potential Energy

After you reread your article from *The Potential for Speed,* discuss the following prompts with your partner:

- What happens in the sport you read about?
- Where does the kinetic energy people get during that sport come from?

Then, answer the question below.

Moving fast is part of the sport you read about. Where does the kinetic energy people get during the sport come from?

____

____

____

____

____

____

Name: ______________________________ Date: ____________________

Exploring Energy in Systems

Use the materials on your tray to build three systems, each composed of two parts, that can give an object kinetic energy. For the first system, use any materials. For the next two, use only magnets.

Use the system to gather evidence about the Investigation Question: *How can magnets cause objects to have kinetic energy?*

Define the parts of each system and answer the questions.

System 1

Name two parts of your system. ____________________ and ____________________

Describe what happened. When was there more potential energy in the system? When was there more kinetic energy in the system?

____

____

____

____

System 2 (magnets only)

Name two parts of your system. ____________________ and ____________________

Describe what happened. When was there more potential energy in the system? When was there more kinetic energy in the system?

____

____

____

____

Name: ______________________________ Date: ________________

Exploring Energy in Systems (continued)

System 3 (magnets only)

Name two parts of your system. ____________________ and ____________________

Describe what happened. When was there more potential energy in the system? When was there more kinetic energy in the system?

____

____

____

____

Name: ______________________________ Date: ________________

Homework: Explanation About Magnets and Kinetic Energy

Explain how the evidence you gathered from reading the article in *The Potential for Speed* and doing the Exploring Energy in Systems activity can help answer the Investigation Question. Try to use all of the words from the Word Bank in your answer.

Word Bank

convert	force	kinetic energy
magnetic field	potential energy	

How can magnets cause objects to have kinetic energy?

____

____

____

____

____

____

____

____

Name: ______________________________ Date: ____________________

Lesson 2.3: Magnetic Force and Potential Energy

All right, student physicists, we still need to figure out where the magnetic launcher system's energy came from and how it got into the system in the first place. In this lesson, you will work in pairs and use the digital Simulation to gather evidence about the relationship between force and energy. You will then work in groups to figure out how energy is transferred into a system.

Unit Question

- Why do magnets move objects in different ways?

Chapter 2 Question

- Where did the energy to launch the model spacecraft come from?

Key Concepts

- A magnetic force can convert potential energy stored in a magnetic field to kinetic energy.

Vocabulary

- attract
- convert
- energy
- kinetic energy
- magnetic field
- model
- potential energy
- repel
- system
- transfer

Digital Tools

- *Magnetic Fields* Simulation

Name: ______________________ Date: ______________

Warm-Up

Complete the Modeling Tool activity: Potential and Kinetic Energy on the next page.

Goal: Create a model to predict how potential energy (PE) and kinetic energy (KE) change when two magnets repel.

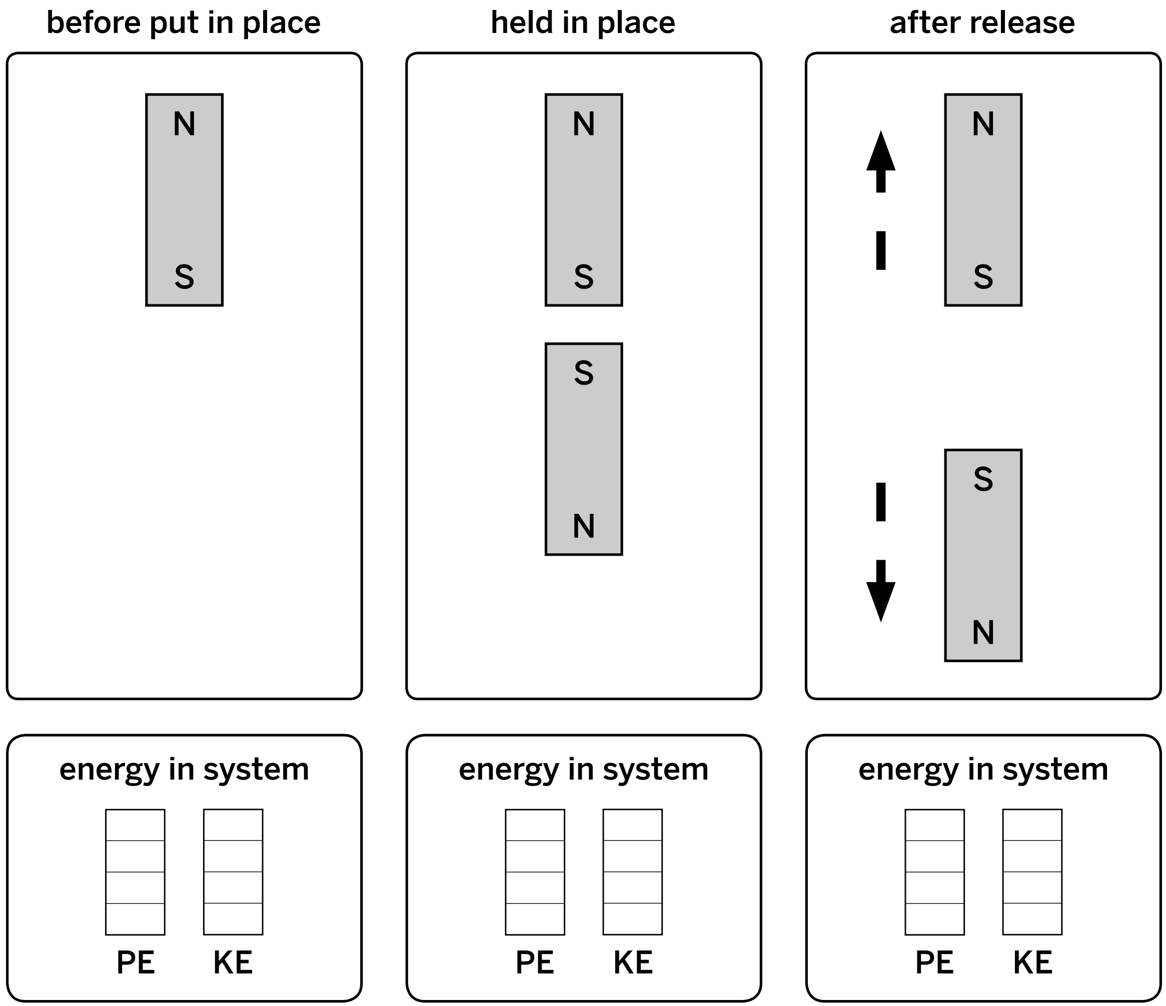
Do:

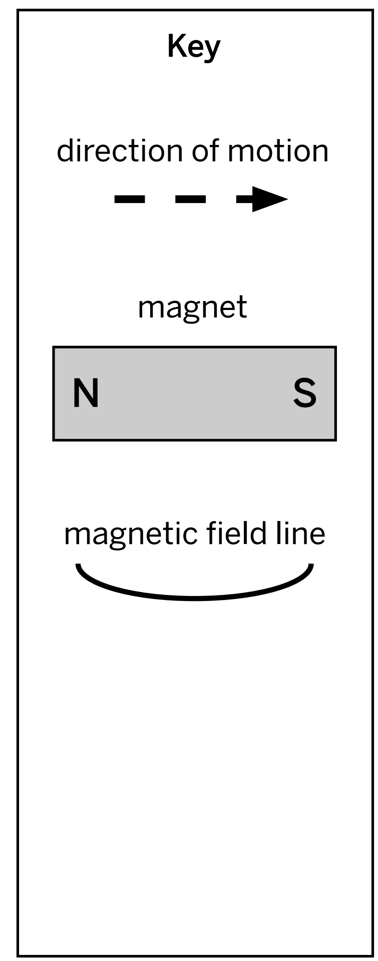
- Shade in the bar graphs under each panel to show how much potential energy and kinetic energy you think the system has at each time.
- Annotate your model to explain the values of potential energy and kinetic energy for each panel.

Name: ______________________ Date: ______________

Modeling Tool: Potential and Kinetic Energy

Shade in the bar graphs under each panel to show your prediction about how much potential energy (PE) and kinetic energy (KE) the system has at each time. Annotate your model to explain the amounts of energy you have chosen for each panel.





Name: ______________________ Date: ______________

Simulating Energy Changes

Part 1: Investigating Changes in Energy

Use the *Magnetic Fields* Simulation to look for evidence and to evaluate the following set of claims about force and potential energy:

> **Claim A:** Potential energy increases when a magnet is moved *with* (in the same direction as) the magnetic force.
>
> **Claim B:** Potential energy increases when a magnet is moved *against* (in the opposite direction from) the magnetic force.

One pair of students will test the claims for attracting magnets, and the other pair will test the claims for repelling magnets. You will share your results.

Follow these steps to test each claim. Observe the potential energy in the system after each step. Record your observations in the data tables on the next page.

1. Decide which pair will test the claims for attracting magnets and which pair will test the claims for repelling magnets. Find the appropriate table for the claim you and your partner are testing.
2. Create a system of magnets that are a medium distance apart. Record the initial potential energy in the first column of your table.
3. Move the second magnet with (in the same direction as) the magnetic force. Record the potential energy in the second column of your table.
4. Now move the second magnet against (in the opposite direction from) the magnetic force. Record the potential energy in the third column of your data table.
5. Share your results with the other members of your group and record the other pair's results in the other data table.

Name: ______________________________ Date: ________________

Simulating Energy Changes (continued)

System of Attracting Magnets

Initial potential energy	Potential energy when moved *with* magnetic force (toward)	Potential energy when moved *against* magnetic force (away)

System of Repelling Magnets

Initial potential energy	Potential energy when moved *with* magnetic force (away)	Potential energy when moved *against* magnetic force (toward)

Part 2: Potential Energy in Magnet Systems

Complete the poll below. It is okay if you are unsure about your answer.

My evidence supports the claim (or claims) that: (choose all that apply)

- ☐ **Claim A:** Potential energy increases when a magnet is moved *with* (in the same direction as) the magnetic force.
- ☐ **Claim B:** Potential energy increases when a magnet is moved *against* (in the opposite direction from) the magnetic force.

Explain how your evidence supports the claim (or claims).

____

____

____

____

____

____

Name: ______________________ Date: ______________

Write and Share 1: Spring and Pom Pom

- Carefully read your evidence card and write an answer to your specific prompt below.
- Answer your prompt, using the vocabulary words listed in the Word Bank below.
- After everyone in your group has had a chance to write, take turns introducing your prompts and sharing your responses.
- While one student is presenting, the other two listen carefully.
- After each student presents, the other students in the group can ask questions or make comments.

Word Bank

force	potential energy	store	system	transfer

Evidence Card A: Spring and Pom Pom

I tried launching a pom pom with a spring a few times. The pom pom didn't launch until after I pushed down on the spring, placed the pom pom on it, and then let go.

The kinetic energy of the pom pom came from potential energy in the system.

How did potential energy get stored in the spring/pom pom system?

Name: ______________________ Date: ______________

Write and Share 2: Magnet and Iron Rod

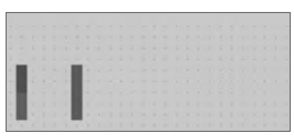
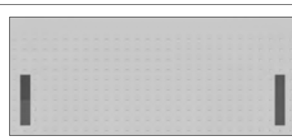
- Carefully read your evidence card and write an answer to your specific prompt below.
- Answer your prompt, using the vocabulary words listed in the Word Bank below.
- After everyone in your group has had a chance to write, take turns introducing your prompts and sharing your responses.
- While one student is presenting, the other two listen carefully.
- After each student presents, the other students in the group can ask questions or make comments.

Word Bank

potential energy	system	transfer	store

Evidence Card B: Magnet and Iron Rod

In the Sim, I observed that the amount of potential energy changed as I moved an iron rod away from a magnet. When the rod and magnet were released, they moved toward each other.

My steps	Potential energy	Arrangement of objects
I placed a magnet and an iron rod in the Sim	948 J	
I moved the iron rod away from the magnet	1003 J	

The kinetic energy of the attracted magnet and iron rod came from potential energy in the system.

How did potential energy get stored in the magnet/iron rod system?

____

____

____

____

____

____

Name: ______________________________ Date: ________________

Write and Share 3: Rubber Band and Pom Pom

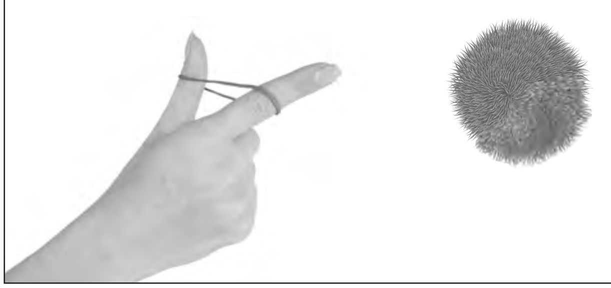
- Carefully read your evidence card and write an answer to your specific prompt below.
- Answer your prompt, using the vocabulary words listed in the Word Bank below.
- After everyone in your group has had a chance to write, take turns introducing your prompts and sharing your responses.
- While one student is presenting, the other two listen carefully.
- After each student presents, the other students in the group can ask questions or make comments.

Word Bank

potential energy	system	transfer	store

Evidence Card C: Rubber Band and Pom Pom

I tried launching a pom pom with a rubber band a few times. The pom pom didn't launch from the rubber band until after I stretched the rubber band and then let go.



The kinetic energy of the launched pom pom came from potential energy in the system.

How did potential energy get stored in the rubber band/pom pom system?

____

____

____

____

____

____

Name: ______________________________ Date: ____________________

Lesson 2.4: Simulating Spacecraft Energy

Hello, student physicists! It's time to wrap up this chapter and take a closer look at Claim 2. You'll use your new knowledge about force and energy to figure things out, so we'll begin by reviewing what you've learned. Then you will simulate the spacecraft launches to see if it's possible that the spacecraft traveled so much faster on Wednesday because the launcher system had much more energy. Let's find an answer for the USA today!

Unit Question

- Why do magnets move objects in different ways?

Chapter 2 Question

- Where did the energy to launch the model spacecraft come from?

Key Concepts

- A magnetic force can convert potential energy stored in a magnetic field to kinetic energy.
- The energy used to move a magnet against a magnetic force is stored as potential energy in the magnetic field.

Vocabulary

- attract
- convert
- energy
- kinetic energy
- magnetic field
- model
- potential energy
- repel
- system
- transfer

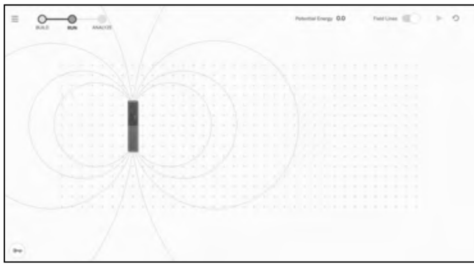
Digital Tools

- *Magnetic Fields* Simulation

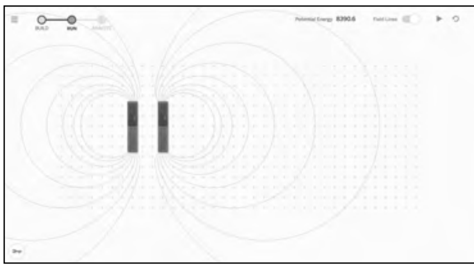
Name: ______________________ Date: ______________

Warm-Up

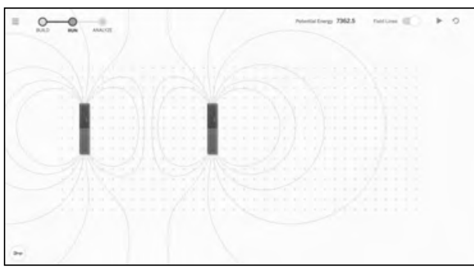
Examine the series of images from the Sim that show potential energy levels (PE) and kinetic energy levels (KE) in only one magnet, as a second magnet is placed, and when both magnets are released. Label each box with letters from the statements below that are true for the image shown in the box. You do not need to use all the letters.



PE = 0 J
KE = 0 J



PE = 8390.6 J
KE = 0 J



PE = 7362.5 J
KE = 1028.1 J

A. Potential energy was stored in the magnet.

B. A force converted potential energy to kinetic energy.

C. The magnets were released.

D. A magnet was moved against a force.

E. Potential energy was transferred into the system.

F. This is not a system.

Name: ____________________ Date: ____________

Simulating Spacecraft Launch Energy

Why did the model spacecraft go so much faster than expected on Wednesday?

Use the *Magnetic Fields* Simulation to gather evidence for or against the claim that much more energy was in the launcher system on Wednesday than on Tuesday.

1. Place one weak magnet toward the left of the screen, with its north pole facing up. Lock this "launcher" magnet in place.
2. Place the second weak magnet, the "spacecraft" magnet, to the right of the launcher magnet with its north pole facing up. Position the spacecraft magnet the indicated number of grid points away from the launcher magnet.
3. Record the initial potential energy.
4. Press RUN to observe the movement of the spacecraft magnet.
5. Press ANALYZE to review the changes in potential energy and kinetic energy during the launch.
6. Record the amounts of potential energy and kinetic energy after the launch in the table below.
7. Return to BUILD and repeat steps 2–6 to simulate the remaining launches.
8. Respond to the questions on the next page.

Modeled test launch	**Potential energy in the system *before* launch**	**Potential energy in the system *after* launch**	**Kinetic energy in the system after launch**
Monday (4 grid points between magnets)			
Tuesday (3 grid points between magnets)			
Wednesday (2 grid points between magnets)			

Name: ______________________________ Date: ____________________

Simulating Spacecraft Launch Energy (continued)

Does this evidence support or refute the claim that there was much more energy in the launcher system on Wednesday than on Tuesday? Explain.

Describe the changes in energy for the tests.

What energy conversion(s) did you see?

Which test resulted in the greatest amount of kinetic energy?

Name: ________________________________ Date: ____________________

Modeling Spacecraft Launch Energy

Complete the Modeling Tool activity: Spacecraft Launch Energy on the next page.

Goal: Create two models to compare the amounts of energy involved in the Tuesday and Wednesday spacecraft launches.

Do:

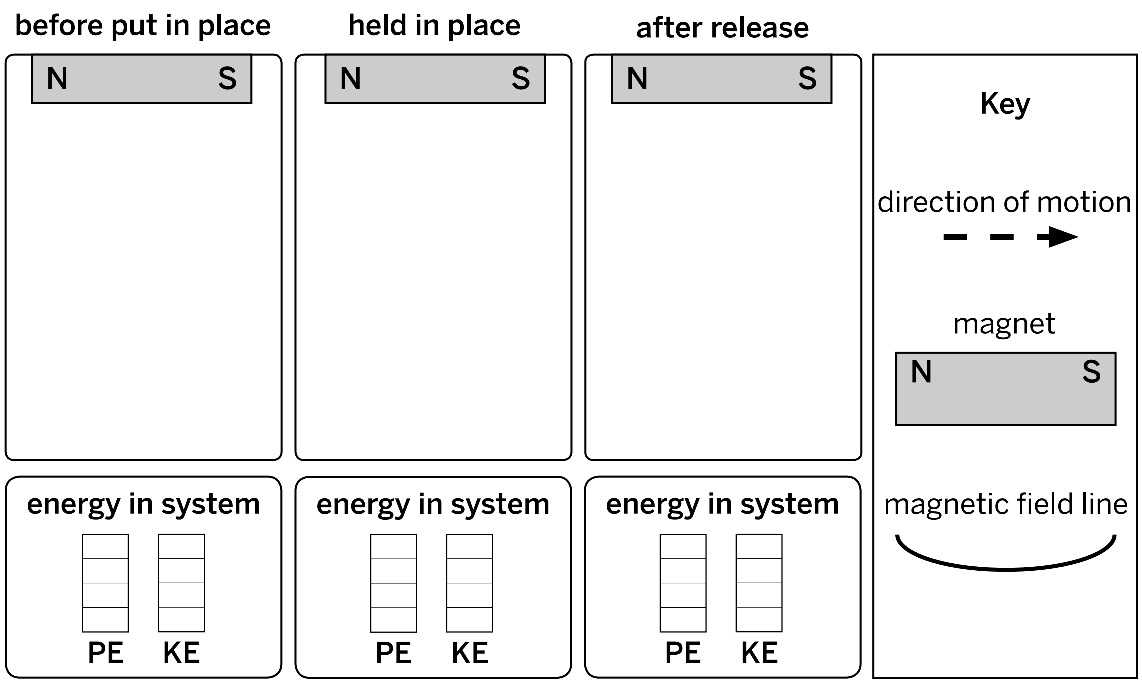
- In the “held in place” panel, show the starting location of the spacecraft by drawing a magnet to represent it.
- In the “after release” panel, show how the spacecraft magnet moved.
- Shade in the amounts of energy in the system for each panel.
- Add magnetic field lines to each panel.
- Annotate your models to indicate parts of the system and show how force is related to potential and kinetic energy.

Name: ______________________ Date: ______________

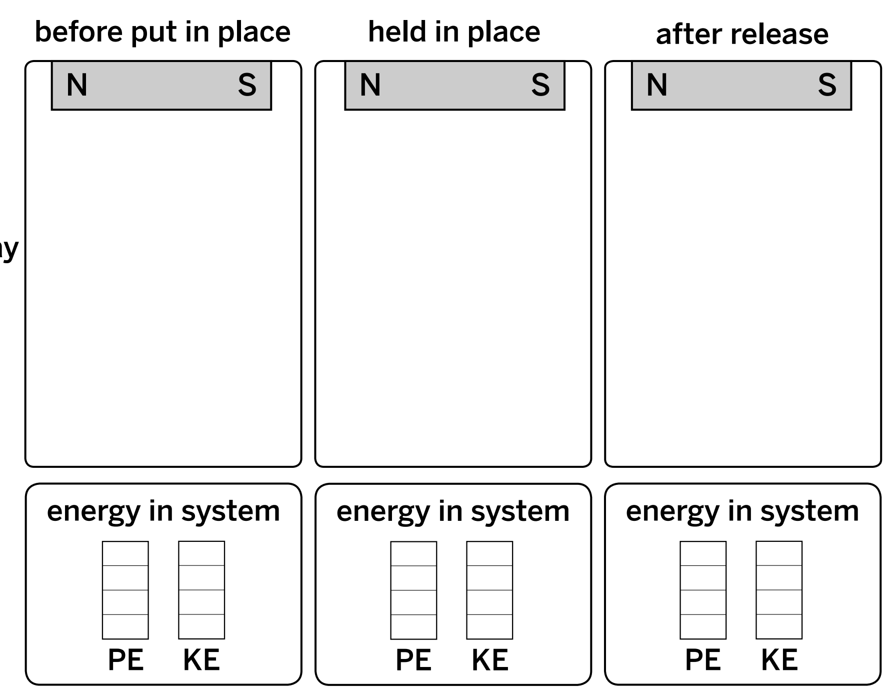
Modeling Tool: Spacecraft Launch Energy

Create two models to compare the amounts of potential and kinetic energy in the Tuesday and Wednesday spacecraft launches. Use a magnet to represent the spacecraft in each launch. Use the symbols shown in the Key in your models.

Tuesday launch



Wednesday launch



Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below and on the next page.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the model spacecraft went so much faster than expected on Wednesday?

1. I understand how the launcher can make the model spacecraft move without touching it. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

2. I understand where the energy to launch the model spacecraft came from. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

3. I understand how force caused different amounts of potential energy to be stored in the launcher system. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

Name: ______________________ Date: ______________

Homework: Check Your Understanding (continued)

4. I understand how potential and kinetic energy changed during the spacecraft launches. (check one).

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

5. What do you still wonder about the magnetic spacecraft launcher?

____

____

____

____

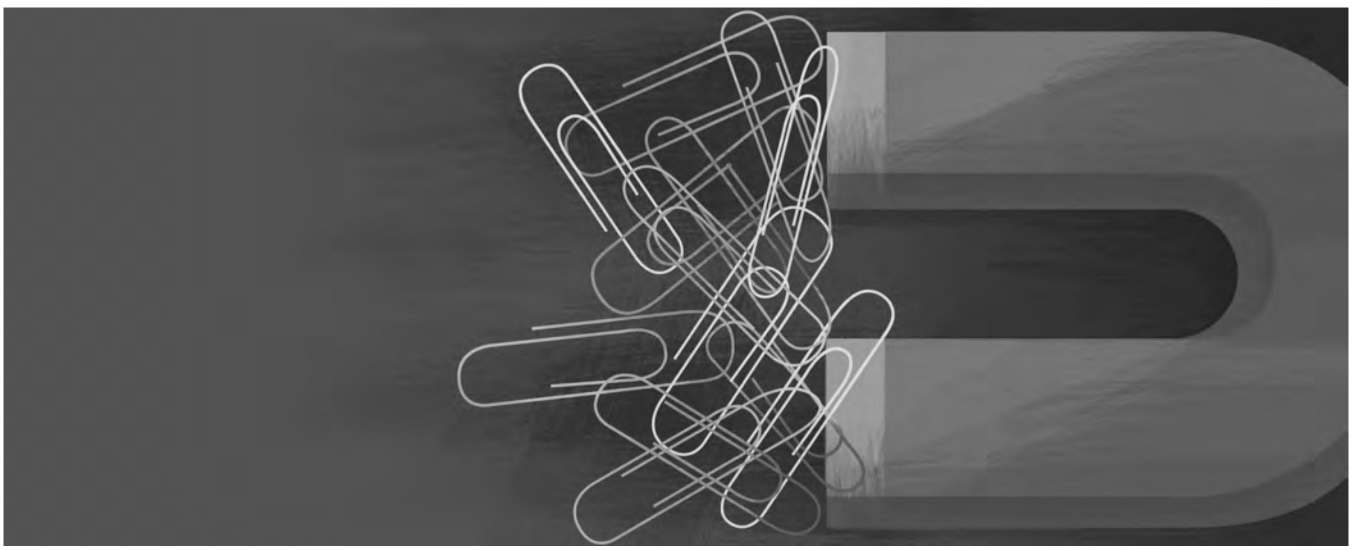
____

____

Name: ______________________________ Date: ________________

Chapter 3: Exploring the Strength of Magnetic Force
Chapter Overview

Now that you know there was more energy in the launcher system on Wednesday, you will evaluate whether the magnetic force was stronger on Wednesday. To do this, you will investigate how moving against a force can store more energy. This will give you the information you need to solve the spacecraft problem. Dr. Shapiro is eager to receive your results!



Name: ______________________________ Date: ______________________

Lesson 3.1: Exploring Energy and Force Strength

Welcome back, student physicists! You've done some excellent work gathering evidence about the claims in this unit. We know that the magnets were not misaligned on Tuesday, and we have some evidence to suggest that there may have been more energy in the system on Wednesday, but we still don't know why. Was the magnetic force different on Wednesday? How can a magnetic force cause different amounts of energy to be stored in a system?

Unit Question

- Why do magnets move objects in different ways?

Chapter 3 Question

- Why was there so much more potential energy stored in the launcher system on Wednesday than on Tuesday?

Vocabulary

- attract
- convert
- energy
- isolate
- kinetic energy
- magnetic field
- magnetic pole
- potential energy
- repel
- system
- transfer
- variable

Name: ______________________________ Date: ____________________

Warm-Up

Safety Note: Strong Magnets
The strong magnets can shatter if dropped on a hard surface and can also pinch skin. Use safety goggles if directed by your teacher, and take care not to throw or drop the magnets.

What is the effect of moving a magnet against a stronger force?

- Arrange two magnets so they are repelling, and push them together.
- One magnet is your "launcher" magnet and the other is your "spacecraft" magnet.
- Release the "spacecraft" magnet.
- Respond to the questions below with your initial ideas.
- Don't worry if you are uncertain. You will have the opportunity to investigate force and energy in this lesson.

1. What happened when you pushed the magnets together? What happened when you let go?

   When I pushed the magnets together, I felt ______________________________.

   When I let go, the spacecraft magnet ______________________________.

2. If you moved the spacecraft magnet against a stronger force, what would happen? (check one)

   - ☐ More potential energy would be stored in the magnetic field, and the spacecraft magnet would travel farther/faster.
   - ☐ Less potential energy would be stored in the magnetic field, and the spacecraft magnet would not travel as far or as fast.
   - ☐ The same amount of potential energy would be stored in the magnetic field, and the spacecraft magnet would travel the same distance at the same speed.
   - ☐ More potential energy would be stored in the magnetic field, but the launcher magnet would travel the same distance at the same speed.

Name: ______________________________ Date: ______________

Exploring Force and Potential Energy

Safety Note: Strong Magnets
The strong magnets can shatter if dropped on a hard surface and can also pinch skin. Use safety goggles if directed by your teacher, and take care not to throw or drop the magnets.

Part 1: Planning Your Investigation

Discuss with your partner how you will test each claim and answer the questions below.

Claim A: More potential energy can be stored by moving against the magnetic force of a **stronger magnet.**

Which variable will you test and which variable(s) will you keep the same?

____

____

____

Claim B: More potential energy can be stored by moving against the magnetic force **closer to a magnet.**

Which variable will you test and which variable(s) will you keep the same?

____

____

____

How will you measure the effect of each variable?

____

____

____

____

____

____

Name: ________________________________ Date: ____________________

Exploring Force and Potential Energy (continued)

Part 2: Gathering Evidence About Claims

What affects the amount of potential energy stored in the magnetic field when a magnet is moved against a magnetic force?

Instructions for Each Claim

1. Using your plan, conduct an experiment to gather evidence about the claim. Revise your plan, if needed.
2. Before you begin, decide how you will set up your data table so there is a place to record each variable and the test results.
3. Conduct each test and record your data.

Evidence About Claim A:

(More potential energy can be stored by moving against the magnetic force of a stronger magnet.)

Complete this sentence:

More potential energy is stored in a system when ______________________________

____ and my

evidence is____.

Name: ______________________________ Date: ____________________

Exploring Force and Potential Energy (continued)

Evidence About Claim B:
(More potential energy can be stored by moving against the magnetic force closer to a magnet.)

Complete this sentence:

More potential energy is stored in a system when ______________________________

____ and my

evidence is ____.

Name: ______________________________ Date: ________________

Homework

Why was the magnetic force stronger in the Wednesday launch?

Today, you experienced how a magnet can have a stronger magnetic force and how moving against this force transfers more potential energy to the magnetic field. If the magnetic force was stronger in the Wednesday launch, it would have caused more energy to be transferred into the launcher system which would give the spacecraft much more kinetic energy.

Record any ideas or questions you have about the question below. It is okay if you are not sure. You will investigate this question further in the next lesson.

Why was the magnetic force produced by the launcher system so much stronger in the Wednesday launch than in the Tuesday launch, even though the spacecraft was moved the same distance closer?

____

____

____

____

____

____

Name: ______________________________ Date: ____________________

Lesson 3.2: Investigating Magnetic Force Strength

Today, you'll gather and discuss your last pieces of evidence about the amount of potential energy stored in the magnetic field when a magnet is moved against a magnetic force. You'll run tests in the Sim and examine diagrams. Soon you'll be ready to explain why moving the launcher and spacecraft the same distance closer for the Wednesday launch had so much more of an effect on the spacecraft's speed than the move that was made for the Tuesday launch.

Unit Question

- Why do magnets move objects in different ways?

Chapter 3 Question

- Why was there so much more potential energy stored in the launcher system on Wednesday than on Tuesday?

Vocabulary

- attract
- convert
- energy
- kinetic energy
- magnetic field
- magnetic pole
- model
- potential energy
- repel
- system
- transfer

Digital Tools

- *Magnetic Fields* Simulation

Name: ______________________________ Date: ____________________

Warm-Up

Today, you will continue to investigate claims about the Investigation Question: *What affects the amount of potential energy stored in the magnetic field when a magnet is moved against a magnetic force?*

Claim A: More potential energy can be stored by moving against the magnetic force of **a stronger magnet.**

Claim B: More potential energy can be stored by moving against the magnetic force **closer to a magnet.**

Answer the questions about Claim A below and Claim B on the next page. It is okay if you are unsure about one or both of the claims. You will gather more evidence about these claims in this lesson.

Do you agree with **Claim A,** More potential energy can be stored by moving against the magnetic force of **a stronger magnet?** (check one)

- ☐ Definitely.
- ☐ I think so.
- ☐ I don't know.
- ☐ I don't think so.
- ☐ Definitely not.

Explain why, using evidence from the activities you have done.

____

____

____

____

____

Name: ______________________________ Date: ________________

Warm-Up (continued)

Do you agree with **Claim B,** More potential energy can be stored by moving against the magnetic force **closer to a magnet?** (check one)

- ☐ Definitely.
- ☐ I think so.
- ☐ I don't know.
- ☐ I don't think so.
- ☐ Definitely not.

Explain why, using evidence from the activities you have done.

____

____

____

____

____

Name: ______________________________ Date: ____________________

Simulating Magnetic Force

What affects the amount of potential energy stored in the magnetic field when a magnet is moved against a magnetic force?

Claim A: More potential energy can be stored by moving against the magnetic force of **a stronger magnet.**

Claim B: More potential energy can be stored by moving against the magnetic force **closer to a magnet.**

Turn on Field Lines and use the SENSOR tool in the *Magnetic Fields* Simulation to find evidence about each claim. Describe your evidence below.

If you have time after you finish finding your evidence, turn to the next page and complete the "Build the Best Launcher" mission.

Describe the tests you conducted and the evidence you found to support or refute **Claim A.**

____

____

____

____

____

Describe the tests you conducted and the evidence you found to support or refute **Claim B.**

____

____

____

____

____

Name: ______________________________ Date: ____________________

Simulating Magnetic Force (continued)

Optional Mission: Build the Best Launcher

Use what you have learned to build the best magnetic launcher system possible in the *Magnetic Fields* Simulation.

Sketch your launcher system. Label the type(s) of magnets you used.

How much potential energy can your launcher system store? ______________________________

Name: ______________________________ Date: ________________

Write and Share 1: Simulation

- Review the evidence card and write an answer to your specific prompt below.
- Answer your prompt, using the vocabulary words listed in the Word Bank below.
- After everyone in your group has had a chance to write, take turns introducing your prompts and sharing your responses.
- While one student is presenting, the other two listen carefully.
- After each student presents, the other students in the group can ask questions or make comments.

Word Bank

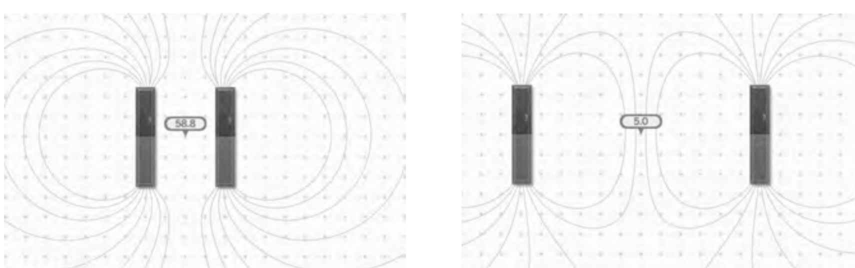
magnetic field	force	potential energy

Other helpful words

closer	farther	stronger	weaker

Evidence Card 1: Simulation

The sensor reading showed that the force was stronger when the magnets were closer together.



What affects the amount of potential energy stored in the magnetic field when a magnet is moved against a magnetic force?

____

____

____

____

____

Name: ______________________ Date: ______________

Write and Share 2: Repelling Magnets

- Review the evidence card and write an answer to your specific prompt below.
- Answer your prompt, using the vocabulary words listed in the Word Bank below.
- After everyone in your group has had a chance to write, take turns introducing your prompts and sharing your responses.
- While one student is presenting, the other two listen carefully.
- After each student presents, the other students in the group can ask questions or make comments.

Word Bank

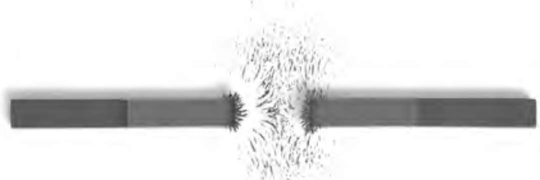
magnetic field	force	potential energy

Other helpful words

closer	farther	stronger	weaker

Evidence Card 2: Repelling Magnets

It was harder to push the magnets together as they got closer together.



What affects the amount of potential energy stored in the magnetic field when a magnet is moved against a magnetic force?

____

____

____

____

____

Name: ______________________________ Date: ________________

Write and Share 3: Attracting Magnets

- Review the evidence card and write an answer to your specific prompt below.
- Answer your prompt, using the vocabulary words listed in the Word Bank below.
- After everyone in your group has had a chance to write, take turns introducing your prompts and sharing your responses.
- While one student is presenting, the other two listen carefully.
- After each student presents, the other students in the group can ask questions or make comments.

Word Bank

magnetic field	force	potential energy

Other helpful words

closer	farther	stronger	weaker

Evidence Card 3: Attracting Magnets

It was harder to pull the magnets apart when they were closer together.

What affects the amount of potential energy stored in the magnetic field when a magnet is moved against a magnetic force?

____

____

____

____

____

Name: ______________________________ Date: ______________________

Write and Share: Revisiting the Claims

After all your group members have shared their sentences, record your current thoughts about the claims, below and on the next page.

What affects the amount of potential energy stored in the magnetic field when a magnet is moved against a magnetic force?

Claim A: More potential energy can be stored by moving against the magnetic force of **a stronger magnet.**

Claim B: More potential energy can be stored by moving against the magnetic force **closer to a magnet.**

Do you agree with **Claim A,** More potential energy can be stored by moving against the magnetic force of **a stronger magnet?** (check one)

- ☐ Definitely.
- ☐ I think so.
- ☐ I don't know.
- ☐ I don't think so.
- ☐ Definitely not.

Explain why, using evidence from the Simulation and hands-on activities.

____

____

____

____

____

Name: ____________________ Date: ____________

Write and Share: Revisiting the Claims (continued)

Do you agree with **Claim B,** More potential energy can be stored by moving against the magnetic force **closer to a magnet?** (check one)

- ☐ Definitely.
- ☐ I think so.
- ☐ I don't know.
- ☐ I don't think so.
- ☐ Definitely not.

Explain why, using evidence from the Simulation and hands-on activities.

____

____

____

____

____

Name: ______________________________ Date: ______________________

Homework: Modeling Force and Energy

Complete the Modeling Tool activity: Force and Energy on the next page.

Goal: Model the system of strong magnets and the system of weak magnets, then compare the energy in each system.

Do:

- Decide which model will show a system of strong magnets and label it “Strong.” Label the other model “Weak.”
- Draw magnetic field lines for each model.
- Shade in the bar graphs for each panel to show the amounts of potential energy and kinetic energy in the system.
- Annotate your models to show where the magnetic force is strongest.

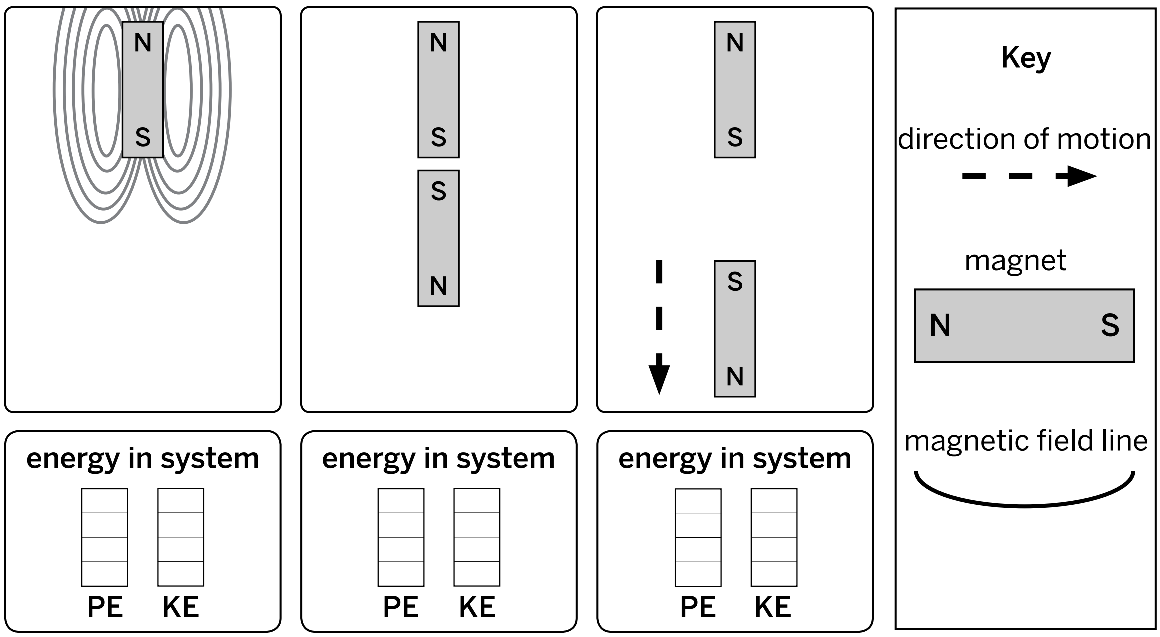
Name: ______________________ Date: ______________

Modeling Tool: Force and Energy

Model the system of strong magnets and the system of weak magnets, then compare the energy in each system. Use the symbols shown in the Key in your models.

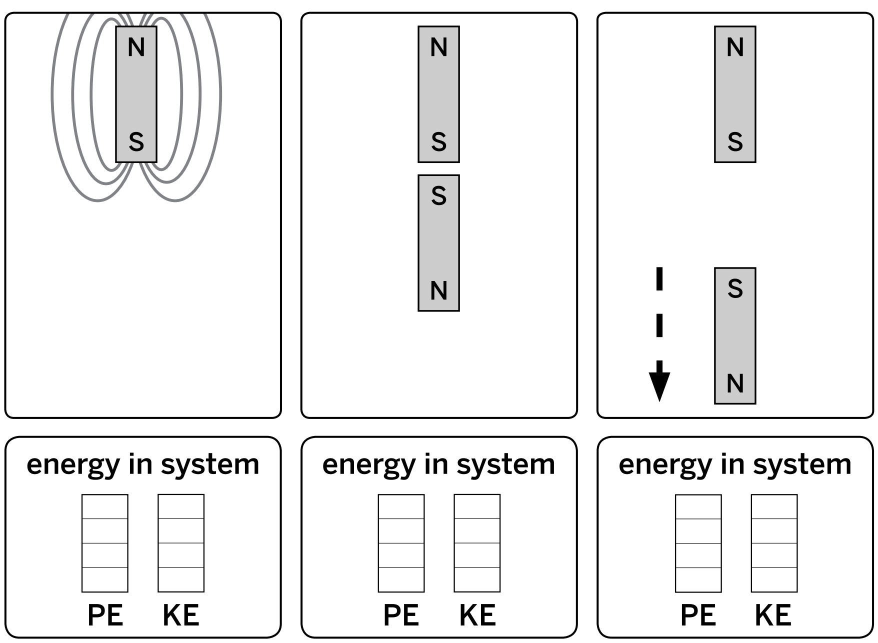
Model 1

before put in place | **held in place** | **after release**



Model 2

before put in place | **held in place** | **after release**



Name: ______________________ Date: ______________

Homework: Reading "Escaping a Black Hole"

Black holes are called black holes because nothing can escape them—not even light! What is it about black holes that allows them to pull other objects toward them with such strong force? Read and annotate the "Escaping a Black Hole" article. Then, answer the questions below.

Why do astronauts on the Moon seem like they're "walking on springs," while on Earth, we are firmly attached to the ground?

____

____

____

____

Why are black holes black?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ________________________ Date: ____________

Lesson 3.3: Modeling the Spacecraft Launches

It is time, student physicists, to analyze the last pieces of data and write a final explanation for the Universal Space Agency. You'll need to use all of your knowledge of potential and kinetic energy, magnetic force, and magnetic fields to get to the bottom of this problem. Why did the spacecraft go so much faster than expected on Wednesday? Let's solve this once and for all!

Unit Question

- Why do magnets move objects in different ways?

Chapter 3 Question

- Why was there so much more potential energy stored in the launcher system on Wednesday than on Tuesday?

Key Concepts

- Moving a magnet against a stronger magnetic force transfers more energy to the magnetic field.
- A magnetic force is stronger closer to a magnet.

Vocabulary

- attract
- convert
- energy
- kinetic energy
- magnetic field
- magnetic field lines
- magnetic pole
- model
- potential energy
- refute
- repel
- system
- transfer

Name: ______________________________ Date: ______________

Warm-Up

Why was the magnetic force stronger on Wednesday?

The spacecraft was moved closer to the launcher by the same amount Wednesday as it was on Tuesday, and yet its speed went up much more. Claim 3 suggests that the magnetic force was much stronger on Wednesday than on Tuesday.

Consider the two subclaims for Claim 3 and answer the question below.

> **Claim 3.A:** The magnetic force was much stronger on Wednesday **because the magnet was stronger.**
>
> **Claim 3.B:** The magnetic force was much stronger on Wednesday **because the magnetic force is stronger closer to the magnets.**

Which claim do you think is more convincing, and why?

____

____

____

____

____

____

Name: ______________________ Date: ______________

Analyzing the Spacecraft Launches

Why did the model spacecraft go so much faster than expected on Wednesday?

Discuss with your partner to decide whether each piece of evidence supports or refutes a claim.

1. Discuss what the information on each card means.
2. Use the discussion questions below to help think about what you would expect to see in the evidence if each claim were true.
3. Place the question at the top of your desk. Place the two claims below the question, side by side. Decide which claim the evidence supports or refutes. Place each piece of evidence below the appropriate claim.
4. After you sort the evidence, answer the questions on the next two pages.

Discussion Questions

- What type of information does this card show?
- What information would you expect to see if Claim 3.A were true and the launcher magnet was stronger on Wednesday?
- What information would you expect to see if Claim 3.B were true and the force was much stronger when the magnets were closer together?

Name: ______________________________ Date: ________________

Analyzing the Spacecraft Launches (continued)

Use the evidence you have sorted to answer each question below and on the next page. You may choose more than one answer.

Which of the USA Evidence Cards support **Claim 2**: Much more energy was in the launcher system on Wednesday than on Tuesday. (choose all that apply)

- ☐ Card A
- ☐ Card B
- ☐ Card C
- ☐ Card D
- ☐ Card E
- ☐ None of the above

Which of the USA Evidence Cards support **Claim 3.A**: The magnetic force was much stronger on Wednesday **because the magnets were stronger.** (choose all that apply)

- ☐ Card A
- ☐ Card B
- ☐ Card C
- ☐ Card D
- ☐ Card E
- ☐ None of the above

Which of the USA Evidence Cards support **Claim 3.B**: The magnetic force was much stronger on Wednesday **because the magnetic force is stronger closer to the magnets.** (choose all that apply)

- ☐ Card A
- ☐ Card B
- ☐ Card C
- ☐ Card D
- ☐ Card E
- ☐ None of the above

Name: ______________________ Date: ______________

Analyzing the Spacecraft Launches (continued)

Which of the claims did your evidence refute? (choose all that apply)

- ☐ **Claim 2**: Much more energy was in the launcher system on Wednesday than on Tuesday.
- ☐ **Claim 3.A**: The magnetic force was much stronger on Wednesday **because the magnets were stronger.**
- ☐ **Claim 3.B**: The magnetic force was much stronger on Wednesday **because the magnetic force is stronger closer to the magnets.**
- ☐ None of the above

Name: ______________________ Date: ______________

Modeling the Spacecraft Launches

Complete the Modeling Tool activity: Spacecraft Launches on the next page.

Goal: Create models of the Tuesday and Wednesday spacecraft launches to explain the difference in speed.

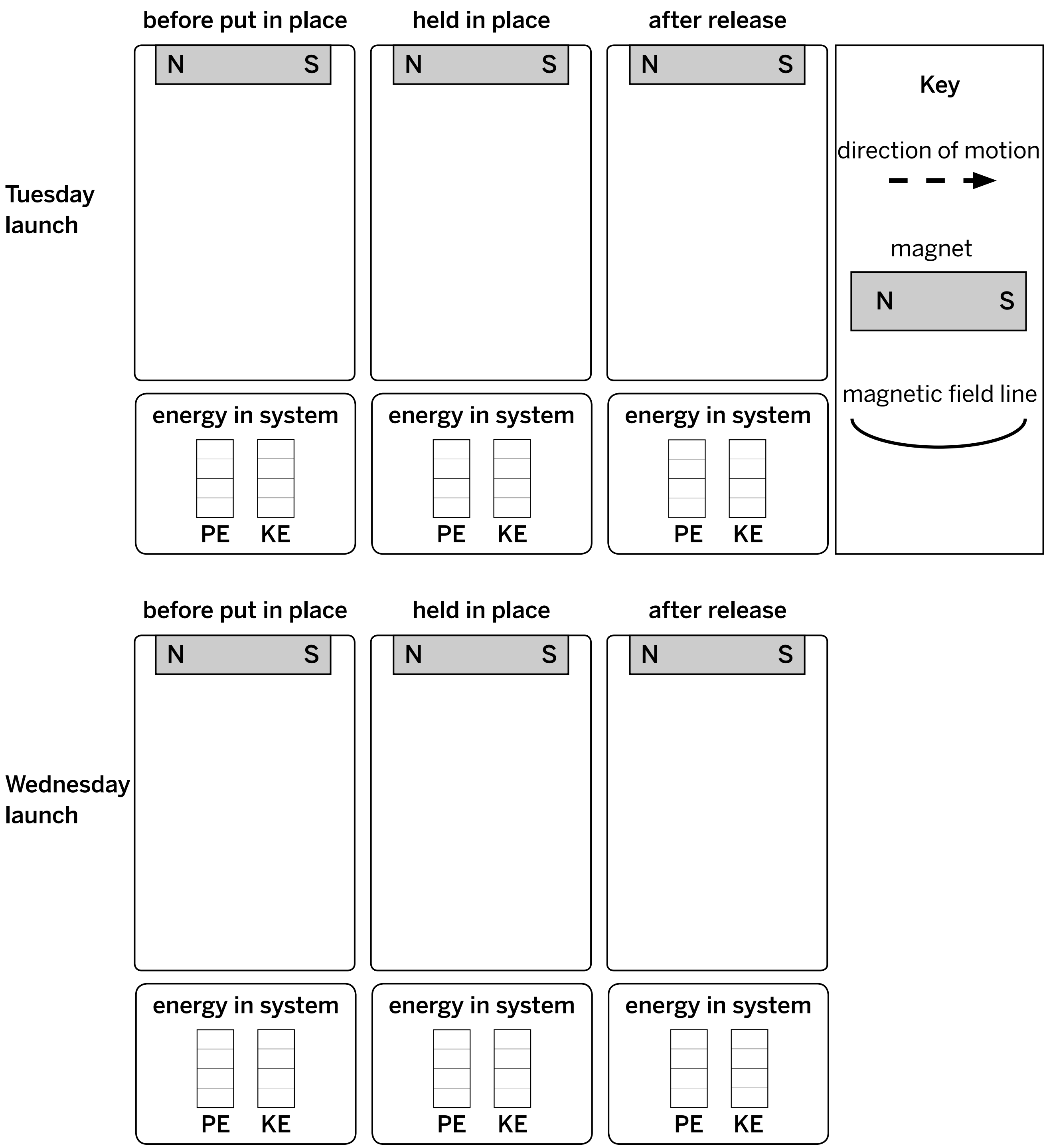
Do:

- In the "held in place" panel, show the starting position of the spacecraft.
- In the "after release" panel, show the motion of the spacecraft.
- Draw magnetic field lines in each panel.
- Annotate your models to show where the magnetic force is strongest.

Name: ____________________ Date: ____________

Modeling Tool: Spacecraft Launches

Create models of the Tuesday and Wednesday spacecraft launches to explain the difference in speed. Use a magnet to represent the spacecraft in each launch. Use the symbols shown in the Key in your models.



Name: ______________________ Date: ______________

Homework: Explaining the Spacecraft Launches

Write your final explanation to the Universal Space Agency. It may be helpful to review the USA Evidence Cards on pages 90–91 or refer to your Modeling Tool activity: Spacecraft Launches as you write.

Word Bank

convert	force	kinetic energy	magnetic field
magnetic pole	potential energy	system	transfer

Transition words and phrases

After	As a result of	Because	If . . ., then . . .
When	Since	Which means . . .	

Why did the model spacecraft go so much faster than expected on Wednesday?

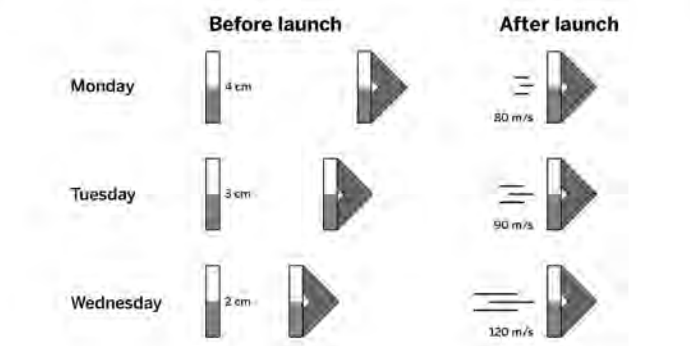
Name: ______________________ Date: ______________

Homework: Explaining the Spacecraft Launches (continued)

Name: ______________________________ Date: ________________

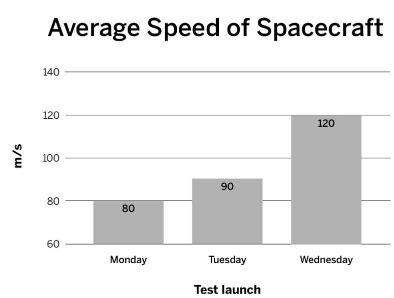
Homework: Explaining the Spacecraft Launches (continued)

Evidence Card A: Distance Between the Launcher and the Spacecraft in Each Launch



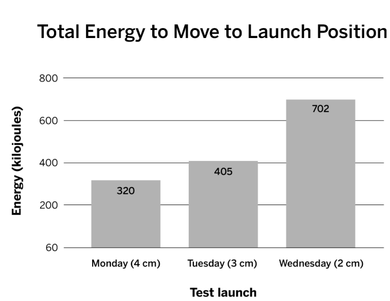
Evidence Card B: Average Speed of the Spacecraft When Launched

Test launch	Average speed of the spacecraft when launched	Increase from previous launch
Monday	80 m/s	- - - -
Tuesday	90 m/s	10 m/s
Wednesday	120 m/s	30 m/s



Evidence Card C: Energy Used to Push Spacecraft to Final Position for Each Launch

The USA scientists calculated how much energy was used to push the spacecraft to each location during the setup process.

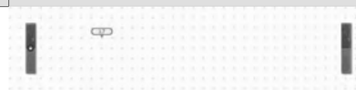


Name: ______________________ Date: ______________

Homework: Explaining the Spacecraft Launches (continued)

Evidence Card D: Simulating the Launches

In the Simulation, the force got much stronger in each launch as the spacecraft magnet moved the same distance closer to the launcher magnet.

Modeled test launch	Strength sensor (milliteslas)	Arrangement of magnets
Monday	1.7	
Tuesday	1.9	
Wednesday	27.9	

Evidence Card E: Energy Used to Push Spacecraft to Initial Position for Each Launch

During the setup process of each launch, the USA scientists recorded how much energy was required to push the spacecraft to an initial position of 4 cm away from the launcher.

Launch date	Total energy to reach initial position 4 cm from launcher *(kilojoules)*
Monday	**320**
Tuesday	**320**
Wednesday	**320**

Name: ______________________________ Date: ____________________

Lesson 3.5: Reviewing Key Ideas and Introducing Electromagnets

During our investigation of the spacecraft problem, we mentioned that the launcher magnets were *electromagnets.* In the upcoming Science Seminar in Chapter 4, you will be evaluating some roller coaster designs that also use electromagnets. But what are electromagnets? How are they different from permanent magnets? How do they work? Why are they useful? Let's go find out!

Unit Question

- Why do magnets move objects in different ways?

Chapter 3 Question

- Why was there so much more potential energy stored in the launcher system on Wednesday than on Tuesday?

Key Concepts

- A magnetic force can attract or repel an object at a distance.
- In a system of magnets, there is a repelling force between like poles and an attracting force between opposite poles.
- The pattern of magnetic field lines around attracting magnets is different from the pattern of magnetic field lines around repelling magnets.
- A magnetic force can convert potential energy stored in a magnetic field to kinetic energy.
- The energy used to move a magnet against a magnetic force is stored as potential energy in the magnetic field.
- Creating a model of a magnetic system and defining its parts helps scientists test and explain the relationship between force and energy.
- Moving a magnet against a stronger magnetic force transfers more energy to the magnetic field.
- A magnetic force is stronger closer to a magnet.

Name: ______________________ Date: ______________

Lesson 3.5: Reviewing Key Ideas and Introducing Electromagnets
(continued)

Vocabulary

- attract
- electromagnet
- energy
- kinetic energy
- magnetic field
- magnetic pole
- potential energy
- repel
- system

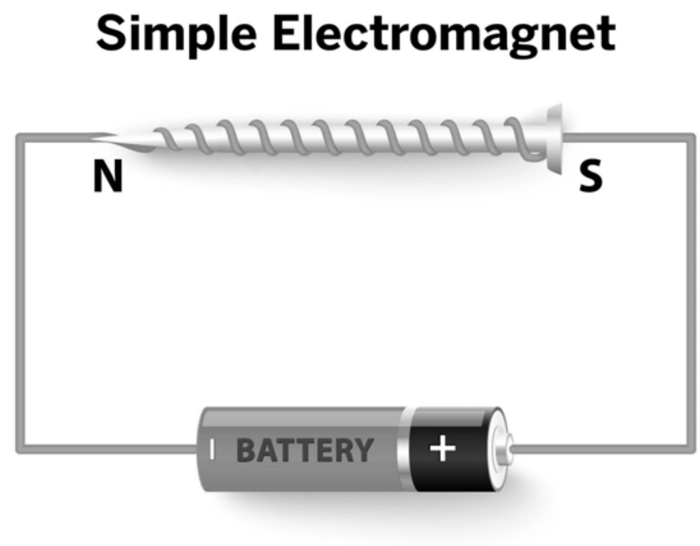
Digital Tools

- *Magnetic Fields* Simulation

Name: ______________________ Date: ______________

Warm-Up

As you watch the video, *How an Electromagnet Works,* make note of how electromagnets work and answer the questions below.



How are electromagnets similar to other magnets?

____

____

____

____

How are electromagnets different from other magnets?

____

____

____

____

Name: ________________________________ Date: ____________________

Blue Group: Testing Electromagnets in the Sim

Part 1: Predictions About Potential Energy

Predict

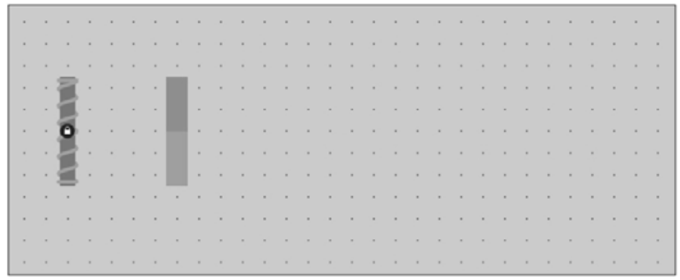
Which setup will have more potential energy? (circle one)

Setup 1 **Setup 2**

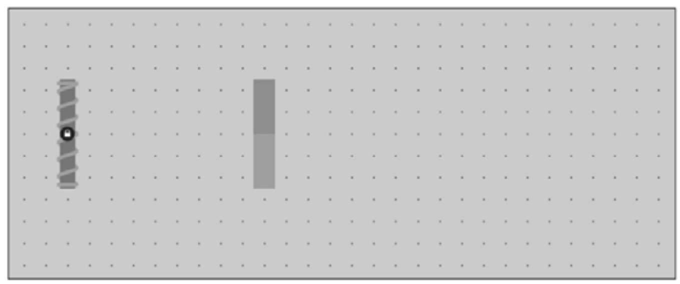
In which setup will the bar magnet have more kinetic energy when you press RUN in the Sim? (circle one)

Setup 1 **Setup 2**

Setup 1



Setup 2



Test

1. Launch the Magnetic Fields Simulation.
2. Switch to Electromagnets Mode and turn Field Lines on.
3. In Build, create Setup 1. Electromagnet A should be placed vertically and not rotated. Be sure to lock the electromagnet in place.
4. Record the amount of potential energy in the system.
5. Press RUN, then press ANALYZE.
6. Record the amount of kinetic energy in the system.
7. Press BUILD and repeat steps 3–6 with Setup 2.
8. Answer the question next to the data table on the next page.

Name: ______________________ Date: ______________

Blue Group: Testing Electromagnets in the Sim (continued)

	Potential energy in Build	**Kinetic energy in Run**
Setup 1		
Setup 2		

Were your results the same as your predictions or different from your predictions? (check one)

- ☐ same
- ☐ different
- ☐ some of each

Part 2: Predictions About Force and Energy

Predict

Imagine moving the bar magnet three grid points closer to the electromagnet in each setup. In which setup will potential energy change more after the move? (circle one)

Setup 1 **Setup 2**

Explain your thinking.

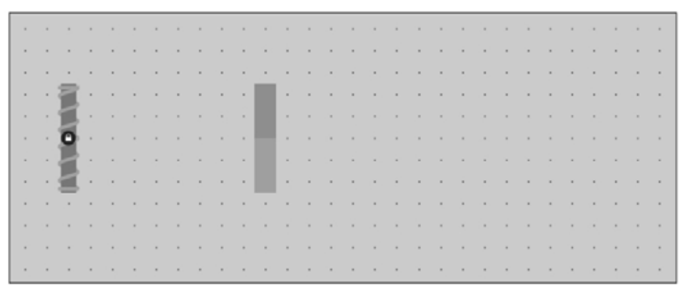
____

____

____

Setup 1

Setup 2



Name: ______________________ Date: ______________

Blue Group: Testing Electromagnets in the Sim (continued)

Test

1. Launch the *Magnetic Fields* Simulation.
2. Switch to Electromagnets Mode and turn Field Lines on.
3. In Build, place the Electromagnet A as shown in both Setups. Electromagnet A should be placed vertically and not rotated. Be sure to lock the electromagnet in place.
4. Press RUN, then press ANALYZE.
5. Drag two SENSOR tools to determine force strength. Place one at five grid points from the electromagnet (the location where you will place the magnet in Setup 1). Place the second one at nine grid points from the electromagnet (the location where you will place the magnet in Setup 2). Record the values in the table below.
6. Return to Build and place the magnet as shown in Setup 1 (five grid points from the electromagnet). Record the potential energy in the data table.
7. Move the bar magnet three grid points closer to the electromagnet, and record the amount of potential energy after the move.
8. Calculate and record the change in potential energy.
9. Press BUILD and repeat steps 6–8 with Setup 2.
10. Answer the question below the data table.

	Force strength at magnet location (mT)	**Potential energy *before* move**	**Potential energy *after* move**	**Change in potential energy**
Setup 1 (five grid points away)				
Setup 2 (nine grid points away)				

Were your results the same as your predictions or different from your predictions? (check one)

- ☐ same
- ☐ different
- ☐ some of each

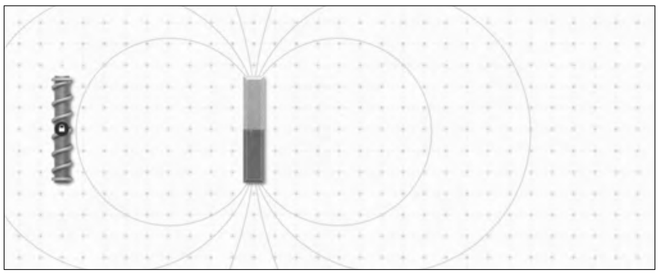
Name: ______________________ Date: ______________

Blue Group: Making Explanations

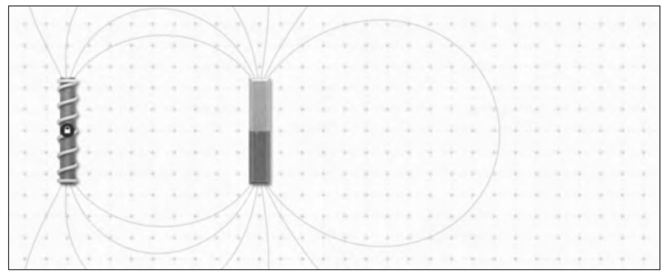
Part 1: Explaining Energy

The images below from the Sim show an electromagnet (locked in place) and a magnet, first with the electricity turned OFF and then with the electricity turned ON.

Electricity OFF



Electricity ON



Discuss the two images with your partner, then complete the statement.

Moving the magnet toward the electromagnet will transfer energy into the system if . . . (check one)

☐ the electricity is OFF.

☐ the electricity is ON.

Use the vocabulary in the Word Bank to complete the following explanation to support your answer.

Moving a magnet against a ______________ transfers energy to the system of magnets, which is stored as ______________ in the ______________.

If the magnet is released, the magnetic force will convert the ______________ to ______________ as the magnet moves.

Word Bank

potential energy	kinetic energy	magnetic force	magnetic field

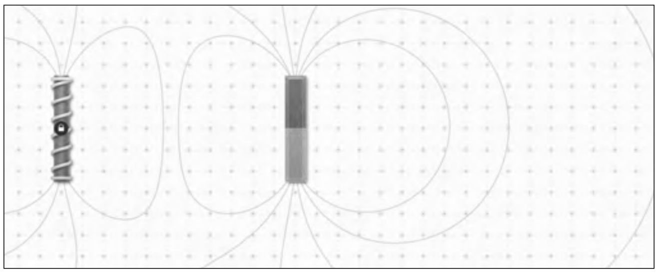
Name: ______________________________ Date: ________________

Blue Group: Making Explanations (continued)

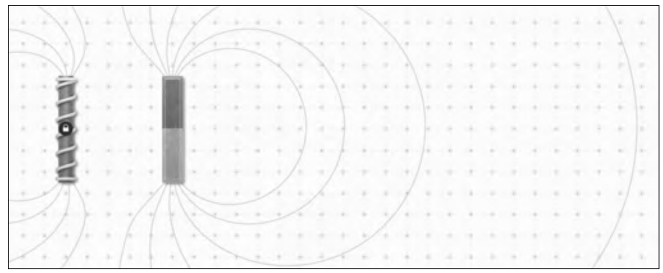
Part 2: Explaining Magnetic Force

The images below from the Sim show an electromagnet (locked in place) and a magnet about to be released.

Setup A



Setup B



Discuss Setups A and B with your partner, then answer the question.

Immediately after it is released, will the magnet move faster in Setup A or in Setup B? (check one)

- ☐ Setup A (magnets farther apart)
- ☐ Setup B (magnets closer together)

Use the vocabulary in the Word Bank to complete the following explanation to support your answer. Not all of the words will be used. Some words may be used more than once.

When the ____________________ is turned on, it will have a ____________________. Moving a ____________________ against a ____________________ by placing it nearby transfers energy to the system of magnets, which is stored as ____________________ in the ____________________, and released as ____________________ when the magnet is allowed to move. Since a ____________________ is stronger ____________________ a magnet, the magnet that is ____________________ the electromagnet when it is turned on will move faster.

Word Bank

potential energy	kinetic energy	magnetic force	magnetic field
magnet	electromagnet	closer to	farther from

Name: ______________________________ Date: ____________________

Green Group: Testing Electromagnets in the Sim

Part 1: Predictions About Force and Energy

Predict

Imagine moving the bar magnet three grid points closer to the electromagnet in each setup. In which setup will potential energy change more after the move? (circle one)

Setup 1 **Setup 2**

Explain your thinking.

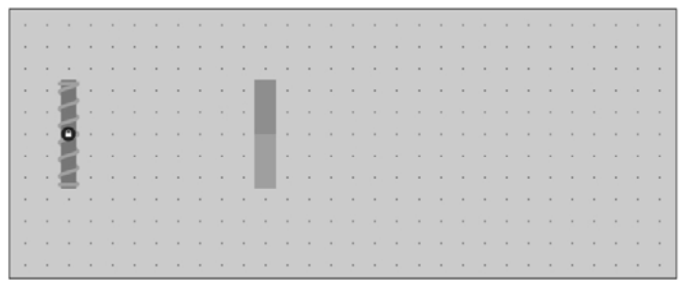
____

____

____

Setup 1

Setup 2



Name: ______________________ Date: ______________

Green Group: Testing Electromagnets in the Sim (continued)

Test

1. Launch the *Magnetic Fields* Simulation.
2. Switch to Electromagnets Mode and turn Field Lines on.
3. In Build, place the Electromagnet A as shown in both Setups. Electromagnet A should be placed vertically and not rotated. Be sure to lock the electromagnet in place.
4. Press RUN, then press ANALYZE.
5. Drag two SENSOR tools to determine force strength. Place one at five grid points from the electromagnet (the location where you will place the magnet in Setup 1). Place the second one at nine grid points from the electromagnet (the location where you will place the magnet in Setup 2). Record the values in the table below.
6. Return to Build and place the magnet as shown in Setup 1 (five grid points from the electromagnet). Record the potential energy in the data table.
7. Move the bar magnet three grid points closer to the electromagnet, and record the amount of potential energy after the move.
8. Calculate and record the change in potential energy.
9. Press BUILD and repeat steps 6–8 with Setup 2.
10. Answer the question below the data table.

	Force strength at magnet location (mT)	**Potential energy *before* move**	**Potential energy *after* move**	**Change in potential energy**
Setup 1 (five grid points away)				
Setup 2 (nine grid points away)				

Were your results the same as your predictions or different from your predictions? (check one)

- ☐ same
- ☐ different
- ☐ some of each

Name: ______________________ Date: ______________

Green Group: Testing Electromagnets in the Sim (continued)

Part 2: Predictions About Iron

Predict

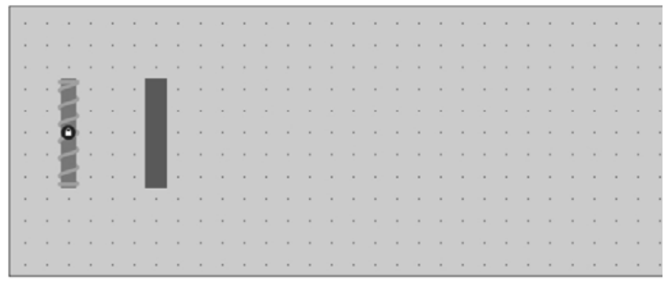
In **Setup 1,** the iron will move . . .

- ☐ **toward** the electromagnet.
- ☐ **away from** the electromagnet.

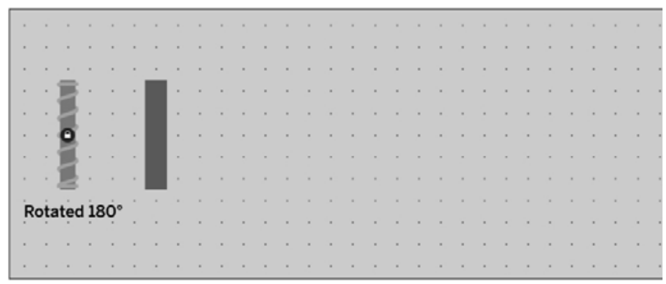
In **Setup 2,** the iron will move . . .

- ☐ **toward** the electromagnet.
- ☐ **away from** the electromagnet.

Setup 1



Setup 2



How can you make the potential energy as high as possible in a magnetic field between one electromagnet and one piece of iron?

____

____

____

Name: ______________________ Date: ______________

Green Group: Testing Electromagnets in the Sim (continued)

Test

1. Launch the *Magnetic Fields* Simulation.
2. Switch to Electromagnets Mode and turn Field Lines on.
3. In Build, create Setup 1. Electromagnet A should be placed vertically and not rotated.
4. Lock the electromagnet in place.
5. Press RUN and observe the movement of the iron. Record your observation in the table below.
6. Press BUILD. Try to make the potential energy as high as possible in the magnetic field. Record your methods in the table below
7. To create Setup 2, remove the lock from the electromagnet, then rotate the electromagnet twice in the same direction to reverse the poles.
8. Repeat steps 4–6 for Setup 2.
9. Answer the question below.

	Did iron move toward or away from the electromagnet?	**What did you do to make potential energy as high as possible in the magnetic field?**
Setup 1		
Setup 2		

Were your results the same as your predictions or different from your predictions? (check one)

- ☐ same
- ☐ different
- ☐ some of each

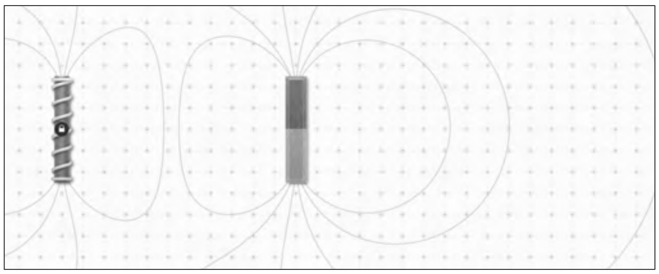
Name: ________________________ Date: ________________

Green Group: Making Explanations

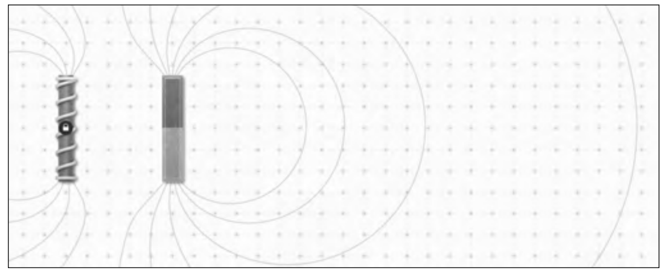
Part 2: Explaining Magnetic Force

This images below from the Sim show an electromagnet (locked in place) and a magnet about to be released.

Setup A



Setup B



Discuss Setups A and B with your partner, then answer the question.

Immediately after it is released, will the magnet move faster in Setup A or in Setup B? (check one)

☐ Setup A (magnets farther apart)

☐ Setup B (magnets closer together)

Use the vocabulary in the Word Bank to complete the following explanation to support your answer. Not all of the words will be used. Some words may be used more than once.

When the ________________ is turned on, it will have a ________________.

Moving a ________________ against a ________________ by placing it nearby transfers energy to the system of magnets, which is stored as ________________ in the ________________, and released as ________________ when the magnet is allowed to move. Since ________________ is stronger ________________ a magnet, the magnet that is ________________ the electromagnet when it is turned on will move faster.

Word Bank

potential energy	kinetic energy	magnetic force	magnetic field
magnet	electromagnet	closer to	farther from

Name: ______________________________ Date: ________________

Purple Group: Testing Electromagnets in the Sim

Part 1: Predictions About Iron

Predict

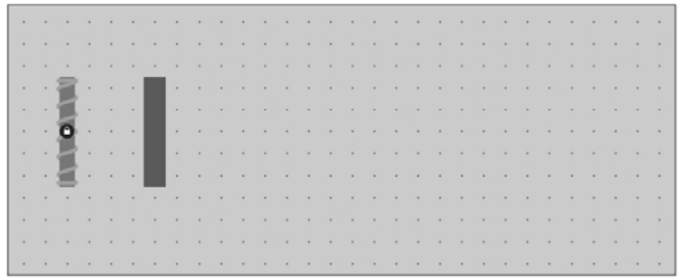
In **Setup 1,** the iron will move . . .

- ☐ **toward** the electromagnet.
- ☐ **away from** the electromagnet.

In **Setup 2,** the iron will move . . .

- ☐ **toward** the electromagnet.
- ☐ **away from** the electromagnet.

Setup 1



Setup 2

How can you make the potential energy as high as possible in a magnetic field between one electromagnet and one piece of iron?

____

____

____

Name: ______________________ Date: ______________

Purple Group: Testing Electromagnets in the Sim (continued)

Test

1. Launch the *Magnetic Fields* Simulation.
2. Switch to Electromagnets Mode and turn Field Lines on.
3. In Build, create Setup 1. Electromagnet A should be placed vertically and not rotated.
4. Lock the electromagnet in place.
5. Press RUN and observe the movement of the iron. Record your observation in the table below.
6. Press BUILD. Try to make the potential energy as high as possible in the magnetic field. Record your methods in the table below
7. To create Setup 2, remove the lock from the electromagnet, then rotate the electromagnet twice in the same direction to reverse the poles.
8. Repeat steps 4–6 for Setup 2.
9. Answer the question below.

	Did iron move toward or away from the electromagnet?	**What did you do to make potential energy as high as possible in the magnetic field?**
Setup 1		
Setup 2		

Were your results the same as your predictions or different from your predictions? (check one)

- ☐ same
- ☐ different
- ☐ some of each

Name: ______________________________ Date: ______________

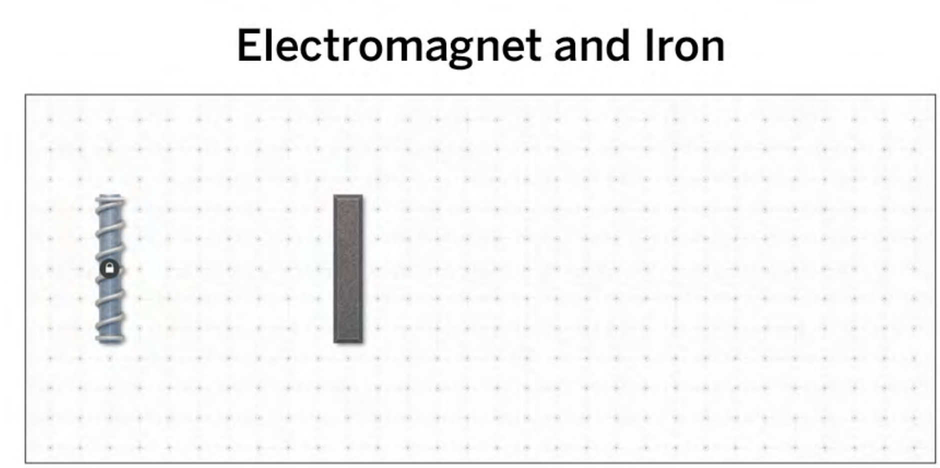
Purple Group: Making Explanations

Reading About Magnets and Iron

1. Read the short article below and discuss it with your partner.

   If you place a piece of iron near a magnet, the magnet will attract the iron. Why does this happen? Strong magnetic fields can create new magnetic fields in some materials, including iron. When the iron is inside a magnetic field, the field creates a north pole and a south pole in the iron. The magnetic poles in the iron align with the poles of the magnet so that the iron and magnet attract. These new poles are temporary, however: if you move the iron away from the magnet, the iron quickly becomes a non-magnet again.

2. Discuss the Electromagnet and Iron setup in the image from the Sim with your partner, then answer the question below.



There is a piece of iron near a locked electromagnet, with the electricity turned OFF. What will happen to the piece of iron when the electricity is turned ON? Why?

____

____

____

Name: ______________________________ Date: ____________________

Purple Group: Making Explanations (continued)

3. Use the vocabulary in the Word Bank to explain why a magnet will never repel a piece of iron.

Word Bank

magnetic field	magnetic force	magnetic pole	potential energy	kinetic energy

____

____

____

____

____

____

Name: ____________________ Date: ____________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below and on the next page.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the model spacecraft went so much faster than expected on Wednesday?

1. I understand how the launcher can make the model spacecraft move without touching it. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

2. I understand where the energy to launch the model spacecraft came from. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

3. I understand how force caused different amounts of potential energy to be stored in the launcher system. (check one)

   - ☐ yes
   - ☐ not yet

Explain your answer choice.

____

____

Name: ____________________ Date: ____________

Homework: Check Your Understanding (continued)

4. I understand how potential and kinetic energy changed during the spacecraft launches. (check one).

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

5. What do you still wonder about the magnetic spacecraft launcher?

____

____

____

____

____

____

Name: ______________________ Date: ______________

Chapter 4: Designing Roller Coasters
Chapter Overview

Fellow student physicists were impressed by your work in solving the spacecraft problem. They have called upon you to help them with their problem: how to design the best electromagnetic rollercoaster. By analyzing evidence and discussing the competing claims with your class, you will decide which design will launch a roller coaster car the fastest.

Name: ______________________________ Date: ____________________

Lesson 4.1: Evaluating Roller Coaster Experiments

What is the best design for an electromagnetic roller coaster with maximum speed? You've been asked by three students to help decide which of their electromagnet roller coaster designs would launch a roller coaster car the fastest. To help decide which design they should submit for a physics contest, you'll need to use everything you learned while solving the spacecraft launcher problem.

Unit Question

- Why do magnets move objects in different ways?

Chapter 4 Question

- Which design will launch the roller coaster car the fastest?

Key Concepts

- A magnetic force can attract or repel an object at a distance.
- In a system of magnets, there is a repelling force between like poles and an attracting force between opposite poles.
- The pattern of magnetic field lines around attracting magnets is different from the pattern of magnetic field lines around repelling magnets.
- A magnetic force can convert potential energy stored in a magnetic field to kinetic energy.
- The energy used to move a magnet against a magnetic force is stored as potential energy in the magnetic field.
- Creating a model of a magnetic system and defining its parts helps scientists test and explain the relationship between force and energy.
- Moving a magnet against a stronger magnetic force transfers more energy to the magnetic field.
- A magnetic force is stronger closer to a magnet.

Vocabulary

- attract
- convert
- electromagnet
- energy
- isolate
- kinetic energy
- magnetic field
- magnetic field lines
- magnetic pole
- potential energy
- repel
- system
- transfer
- variable

Name: ______________________ Date: ______________

Warm-Up

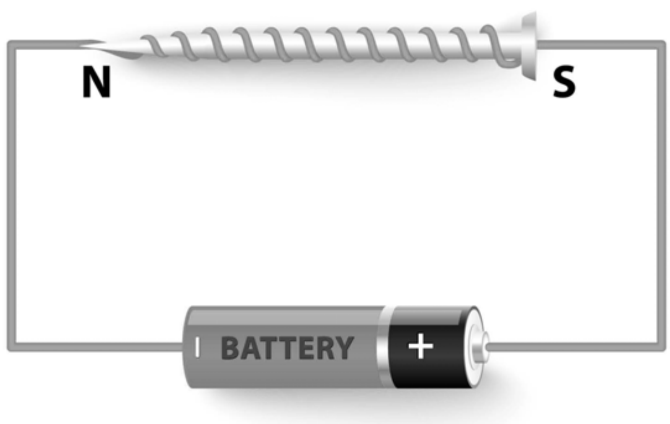
Read the short article below and answer the questions. Then, discuss your answers with your partner.

Electromagnets

An electromagnet can be created using a battery, some wire, and an iron nail. The wire is coiled around the nail a bunch of times and then connected to a battery. When the electric current from the battery runs through the wire, suddenly the nail will repel or attract magnets!

Running electric current through the wire creates a magnetic field around the wire-coiled nail. If you turn the electricity up, the magnetic field gets stronger. If you turn it off, the magnetic field will no longer exist. If you change the direction that the electricity flows in through the wire, you can even reverse the poles of the magnetic field!

Simple Electromagnet



What might be some advantages of using electromagnets instead of permanent magnets?

____

____

____

How are electromagnets made?

____

____

____

Name: ______________________________ Date: ______________________

Annotating Competing Designs

- Closely examine and annotate each design to record your observations and questions.
- Note the ways that the designs are different and record your ideas about how the differences will affect the speed of the roller coaster car.
- Think about the key concepts you learned while investigating the spacecraft problem, which are posted on the classroom wall.

After you have considered and annotated each design, discuss the following question with your partner:

- Which design do you think will launch the roller coaster car the fastest?

This is your initial thinking. It is okay if you are unsure.

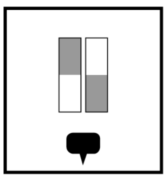
Name: ______________________ Date: ______________

Evaluating Experiments

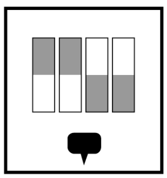
Evidence Card E: What is the effect of the arrangement of magnetic poles?

Experiment Description

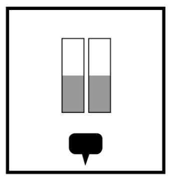
- Three different arrangements of magnets were made.
- Two of these arrangements had two magnets; the other one had four magnets.
- A sensor to measure magnetic force was placed 1 cm from each set of magnets.



sensor reading: 0.9 mT



sensor reading: 4.3 mT



sensor reading: 1.9 mT

Is the test variable isolated?

1. What variable was being tested?
2. How were the effects measured?
3. Which test variables were changed and which stayed the same?
4. Can you conclude that the differences in the results are due to the effect of the test variable?

For each evidence card, determine:

- What variable was tested?
- How were the effects measured?
- Which variables were changed and which stayed the same in the tests?
- Can you conclude that the differences in results are due to the effect of the test variable?

Select which evidence can be eliminated because it did not isolate variables. (check all that apply)

- ☐ Evidence Card A: Magnetic pole arrangement
- ☐ Evidence Card B: Number of wire coils
- ☐ Evidence Card C: Rail material
- ☐ Evidence Card D: Distance between the car and launcher
- ☐ None should be eliminated.

Name: ________________________________ Date: ____________________

Lesson 4.2: Evaluating Roller Coaster Design Claims

Which design will launch the roller coaster car the fastest? In the previous lesson, you discarded evidence from experiments that did not isolate variables. Today, you will be able to gather new evidence about these variables and then analyze all of the reliable evidence. Which of the variables do you think is the most important? Who has the best design?

Unit Question

- Why do magnets move objects in different ways?

Chapter 4 Question

- Which design will launch the roller coaster car the fastest?

Key Concepts

- A magnetic force can attract or repel an object at a distance.
- In a system of magnets, there is a repelling force between like poles and an attracting force between opposite poles.
- The pattern of magnetic field lines around attracting magnets is different from the pattern of magnetic field lines around repelling magnets.
- A magnetic force can convert potential energy stored in a magnetic field to kinetic energy.
- The energy used to move a magnet against a magnetic force is stored as potential energy in the magnetic field.
- Creating a model of a magnetic system and defining its parts helps scientists test and explain the relationship between force and energy.
- Moving a magnet against a stronger magnetic force transfers more energy to the magnetic field.
- A magnetic force is stronger closer to a magnet.

Name: ______________________ Date: ______________

Lesson 4.2: Evaluating Roller Coaster Design Claims (continued)

Vocabulary

- attract
- convert
- electromagnet
- energy
- isolate
- kinetic energy
- magnetic field
- magnetic field lines
- magnetic pole
- potential energy
- repel
- system
- transfer
- variable

Digital Tools

- *Magnetic Fields* Simulation

Name: ______________________ Date: ______________

Warm-Up

In the previous lesson, you evaluated which experiments provided the strongest evidence about the roller coaster designs. The experiments recorded on Card B and Card D did not isolate variables, so they were eliminated.

Today, you will use the *Magnetic Fields* Simulation to collect more reliable data about the two variables that were tested on the eliminated cards: the number of wire coils on the electromagnet and the distance between the car and launcher.

1. How does the number of wire coils on an electromagnet affect the strength of magnetic force?

Describe how you will set up tests with isolated variables in the Sim to answer this question.

What will you change?

____

____

What will you keep the same?

____

____

What will you measure?

____

____

Name: ______________________ Date: ______________

Warm-Up (continued)

2. How does the distance between the car and launcher affect the speed of the car?

Describe how you will set up tests with isolated variables in the Sim to answer this question.

What will you change?

____

____

What will you keep the same?

____

____

What will you measure?

____

____

Name: ______________________________ Date: ________________

Testing Roller Coaster Variables

Refer to the Warm-Up as you finalize a plan with your partner for conducting experiments in the Sim. Your goal is to gather reliable data about the effects of two variables: different numbers of coils on the electromagnet, and different distances between the car and launcher.

Launch the *Magnetic Fields* Simulation and begin your experiments.

Remember to:

- Lock electromagnets in place
- Isolate your variables to be sure your conclusions make sense

Complete Evidence Cards F and G as you collect your data.

Name: ______________________________ Date: ________________

Analyzing Roller Coaster Evidence

Determine what the data on each card means.

1. Review your annotations from the last lesson about the quality of the experimental evidence on each evidence card.
2. Shift your focus to the **results** of the experiments on the other side of the cards.
3. Annotate each of the remaining evidence cards (A and C) and your new evidence cards (F and G), thinking carefully about what the results tell you about roller coaster design. You may want to consider these questions:
   - Which variable was being tested?
   - Did changing this variable seem to have a big or small effect on the launch speed?
   - What does the result say about how the variable affects the launch speed?

Name: ______________________________ Date: ________________

Evaluating Roller Coaster Designs

Decide which evidence cards support each claim.

1. Lay the design claims at the top of your desk, side by side.
2. Discuss each evidence card (A, C, F, G) with your partner, using the following questions:
   - What is the effect of the variable tested on launch speed?
   - Which of the four variables has the greatest effect on the launch speed?
3. Place each evidence card under the design claim you feel it supports or goes against. If you are unsure, you can place the card off to the side.
   - If the evidence supports a design claim, write "Supports (Christina's, Nevi's, or Dorian's) design" on that card.
   - If the evidence refutes a design claim, write "Goes against (Christina's, Nevi's, or Dorian's) design" on that card.
   - If the evidence connects with another evidence card, write "Connects with Evidence Card (A, C, F, or G)" on that card.
4. Decide which design claim is best supported by the available evidence.
5. When you and your partner are satisfied with your evidence card sorts and the design claim you have chosen, respond to the questions:

Based on all the evidence you have seen, which design do you think will launch the roller coaster car the fastest? (check one)

- ☐ Christina's design
- ☐ Nevi's design
- ☐ Dorian's design

Explain your choice. What evidence suggests that this design will launch the roller coaster car the fastest?

____

____

____

____

Name: ______________________________ Date: ________________

Lesson 4.3: The Science Seminar

Which design will launch the roller coaster car the fastest? In today's Science Seminar, you and your classmates will discuss the evidence, listen to one another's ideas, and try to arrive at an understanding of what is most important when designing an electromagnetic roller coaster. After hearing your classmates and participating in the discussion, you will be ready to write a convincing scientific argument.

Unit Question

- Why do magnets move objects in different ways?

Chapter 4 Question

- Which design will launch the roller coaster car the fastest?

Key Concepts

- A magnetic force can attract or repel an object at a distance.
- In a system of magnets, there is a repelling force between like poles and an attracting force between opposite poles.
- The pattern of magnetic field lines around attracting magnets is different from the pattern of magnetic field lines around repelling magnets.
- A magnetic force can convert potential energy stored in a magnetic field to kinetic energy.
- The energy used to move a magnet against a magnetic force is stored as potential energy in the magnetic field.
- Creating a model of a magnetic system and defining its parts helps scientists test and explain the relationship between force and energy.
- Moving a magnet against a stronger magnetic force transfers more energy to the magnetic field.
- A magnetic force is stronger closer to a magnet.

Vocabulary

- attract
- convert
- electromagnet
- energy
- isolate
- kinetic energy
- magnetic field
- magnetic field lines
- magnetic pole
- potential energy
- repel
- system
- transfer
- variable

Name: ______________________________ Date: ____________________

Warm-Up

In today's Science Seminar, you and your classmates will discuss the evidence, listen to one another's ideas, and try to arrive at the best understanding of what is important when designing an electromagnetic roller coaster.

Review the design claims, evidence cards, and the roller coaster design you wrote about in the last lesson. If needed, revise your writing below.

Explain your choice. What evidence suggests that this design will launch the roller coaster car the fastest?

____

____

____

____

____

____

Identify one evidence card that is the most convincing piece of evidence. Draw a star on that evidence card.

Name: ________________________________ Date: ____________________

Preparing for the Science Seminar

1. Take turns with your partner sharing which design you think will launch the roller coaster car the fastest.
2. Use your Warm-Up response and starred evidence card to help you share ideas.
3. Use the Argumentation Sentence Starters on the scientific argumentation wall to help you respond to your partner's ideas.
4. Refer to the design claims and evidence cards as needed.

Which design will launch the roller coaster car the fastest?

- Christina's Design
- Nevi's Design
- Dorian's Design

Argumentation Sentence Starters

- I think this evidence supports this claim because . . .
- I don't think this evidence supports this claim because . . .
- I agree because . . .
- I disagree because . . .
- Why do you think that?

Name: ________________________________ Date: ____________________

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is:	

Name: ______________________ Date: ______________

Homework: Writing a Scientific Argument

Write an argument to answer the question *Which design will launch the roller coaster car the fastest?*

Getting Ready to Write

A. Choose one of the three design claims below.

- ☐ Christina's design will launch the roller coaster the fastest.
- ☐ Nevi's design will launch the roller coaster the fastest.
- ☐ Dorian's design will launch the roller coaster the fastest.

B. Next, choose all the evidence that supports your argument. You may look back at your evidence cards.

- ☐ Evidence Card A: Magnetic Pole Arrangement
- ☐ Evidence Card C: Rail Material
- ☐ Evidence Card F: Number of Wire Coils
- ☐ Evidence Card G: Distance Between the Car and Launcher

Write Your Argument

C. Now you are ready to write your argument. Be sure to

1. include the design claim (from Step A) that you think is strongest,
2. describe the force that launches the car forward,
3. use evidence (from Step B) to support your thinking and explain why you think the design claim you chose is the strongest, and
4. refer to the Scientific Argument Sentence Starters for help in constructing your argument.

Scientific Argument Sentence Starters	
Describing evidence:	**Describing how the evidence supports the claim:**
The evidence that supports my claim is . . .	If ____________, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since . . .
This evidence shows that . . .	Based on the evidence, I conclude that . . .
	This claim is stronger because . . .

Name: ______________________ Date: ______________

Homework: Writing a Scientific Argument (continued)

Name: ______________________________ Date: ________________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand that evidence is stronger when the variable being tested is isolated, so only one variable is changed at a time. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

2. What are the most important things you learned in this unit about why magnets move objects in different ways?

____

____

____

____

____

3. What questions do you still have?

____

____

____

____

____

Magnetic Fields Glossary

attract: to pull objects toward one another

atraer: jalar los objetos unos a otros

convert: to change from one type to another

convertir: cambiar de un tipo a otro

electromagnet: a type of magnet in which the magnetic field is produced by an electric current

electroimán: un tipo de imán en el que el campo magnético es producido por una corriente eléctrica

energy: the ability to make things move or change

energía: la capacidad de hacer que las cosas se muevan o cambien

force: a push or a pull that can change the motion of an object

fuerza: un empujón o un jalón que puede cambiar el movimiento de un objeto

isolate: to separate or set apart

aislar: separar o apartar

kinetic energy: the energy that an object has because it is moving

energía cinética: la energía que tiene un objeto porque se está moviendo

magnetic field: the space around a magnet in which magnetic forces can act on objects

campo magnético: el espacio que rodea a un imán, en el cual las fuerzas magnéticas pueden actuar sobre los objetos

magnetic field line: a line that connects opposite magnetic poles and represents the strength and direction of the magnetic field

línea de campo magnético: una línea que conecta polos magnéticos opuestos y que representa la fuerza y la dirección del campo magnético

magnetic pole: one of the two opposite ends of a magnet

polo magnético: uno de los dos extremos opuestos de un imán

model: an object, diagram, or computer program that helps us understand something by making it simpler or easier to see

modelo: un objeto, diagrama o programa de computadora que nos ayuda a entender algo haciéndolo más simple o fácil de ver

potential energy: the energy that is stored in an object or system

energía potencial: la energía que está almacenada en un objeto o sistema

refute: to provide evidence that goes against a claim

refutar: proporcionar evidencia en contra de una afirmación

repel: to push objects away from each other

repeler: empujar los objetos alejándose unos de otros

system: a set of interacting parts forming a complex whole

sistema: un conjunto de partes que interactúan formando un todo complejo

transfer: to move from one object to another or one place to another

transferir: mover de un objeto a otro o de un lugar a otro

variable: something that can be changed and may be measured

variable: algo que se puede cambiar y que se puede medir

Lawrence Hall of Science:
Program Directors: Jacqueline Barber and P. David Pearson
Curriculum Director, Grades K–1: Alison K. Billman
Curriculum Director, Grades 2–5: Jennifer Tilson
Curriculum Director, Grades 6–8: Suzanna Loper
Assessment and Analytics Director: Eric Greenwald
Learning Progressions and Coherence Lead: Lauren Mayumi Brodsky
Operations and Project Director: Cameron Kate Yahr
Student Apps Director: Ari Krakowski
Student Content Director: Ashley Chase

Leadership Team: Jonathan Curley, Ania Driscoll-Lind, Andrew Falk, Megan Goss, Ryan Montgomery, Padraig Nash, Kathryn Chong Quigley, Carissa Romano, Elizabeth Shafer, Traci K. Shields, Jane Strohm

***Magnetic Fields: Launching a Spacecraft* Unit Team:**

Stacy Au-yang
Elizabeth Ball
Candice Bradley
Barbara Clinton
Benton Cheung
Paul Daubenmire
Jacqueline Felipe
Juliana Tringali Golden
Sybil Lockhart
M. Lisette Lopez
Deirdre MacMillan
Julia D. Neal
Michelle Z. Rodriguez
Natalie Roman
Joshua A. Willis

Amplify:

Irene Chan
Samuel Crane
Shira Kronzon
Charvi Magdaong
Thomas Maher
Rick Martin
Matt Reed
Eve Silberman
Steven Zavari

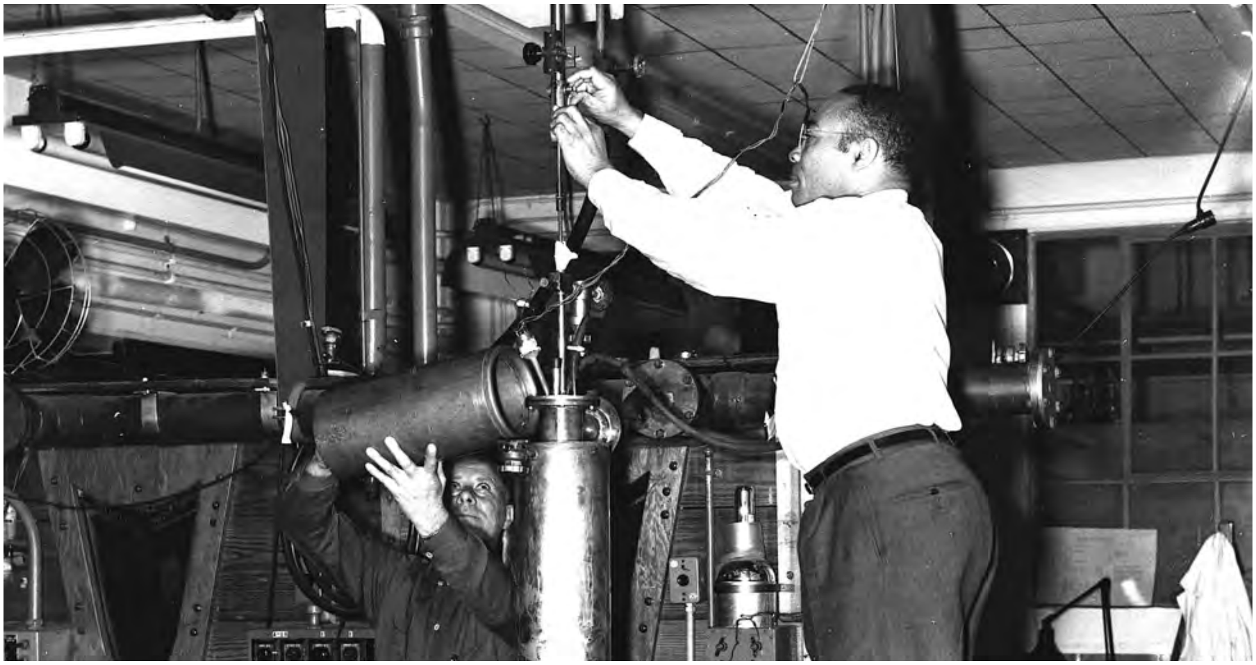
Credits:
Illustration: Cover: Tory Novikova
Photographs: Pages 50, 52, 74–75, 94, 113: Shutterstock

Magnetic Fields:

Launching a Spacecraft

Article Compilation

Table of Contents: Articles



Warren Henry was a scientist who studied how magnets behave at very low temperatures. Here, he adjusts some of his lab equipment.

Meet a Scientist Who Studied Magnets

Warren Henry was born in 1909 on a peanut farm in rural Alabama, and he was exposed to scientific ideas early on. Both of his parents had attended a college called the Tuskegee Institute (now Tuskegee University), where they became friends with the famous scientist George Washington Carver. Carver spent his summers living and doing research on the Henrys' farm, and Warren was sometimes allowed to go on evening walks with his parents and their guest.

As a young man, Henry also attended the Tuskegee Institute, just as his parents had. He then studied at Atlanta University, earning a Master's degree in chemistry. During this time, he taught classes at Spelman College and Morehouse College.

For the first half of Henry's life, schools were separated by race, and he was only allowed to attend and teach at schools for African-American students. These schools had much less science equipment and fewer books and other supplies compared with schools for white students. In 1941, Henry earned a Ph.D. in physical chemistry from the University of Chicago, where students of all races were allowed to study. His Ph.D. should have guaranteed him a job at any university, but instead he was only offered jobs at colleges meant for African-American students. Even after Henry had studied and worked at many different universities, some universities would not allow him to use their science equipment because of his race.

Despite the racism he experienced, Henry became famous and well-respected for his work with magnets. He invented new ways of using magnets to find submarines underwater and worked on using magnets to make vehicles that could hover, or float, above the ground. Henry also spent many years studying the behavior of magnets and other materials at very cold temperatures, which is different from the way they behave at warmer temperatures. For many years, he was considered the greatest expert in the United States on low-temperature magnetism.

Henry retired from teaching and research in 1977, but he remained active in organizations that support African-American scientists and engineers until his death in 2001.

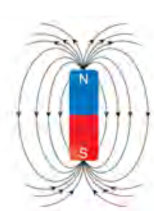
Compasses tell us which way is north. That helps us to find south, east, and west, too.

Earth's Geomagnetism

If you've ever used a compass, you've seen that you can turn it in different directions and the magnetic needle inside rotates to point north again, as if it had a mind of its own. This small magnetic needle is actually pushed and pulled by powerful magnetic forces that envelop Earth. Our planet is surrounded by a huge magnetic field that reaches from Earth's core all the way into space.

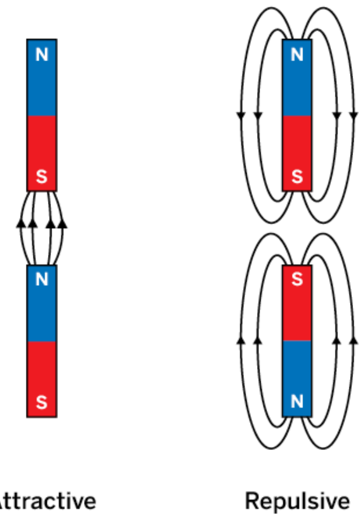
Magnetic forces like those caused by Earth's geomagnetic field may seem mysterious. These forces act on objects at a distance, and we can't see or touch them. To help visualize magnetic forces, scientists model them using magnetic field lines. These scientific models help scientists predict and explain how magnetic forces work. In a model of a single magnet, lines are drawn looping outward between opposite magnetic poles.

Compasses align with Earth's magnetic field. No matter where the compass is on Earth or which way you turn it, the needle always points north. This means the needle points in different directions at different places on Earth's surface.



In a model of a single magnet, magnetic field lines come out of the north side of the magnet, loop outward, and enter the south side of the magnet.

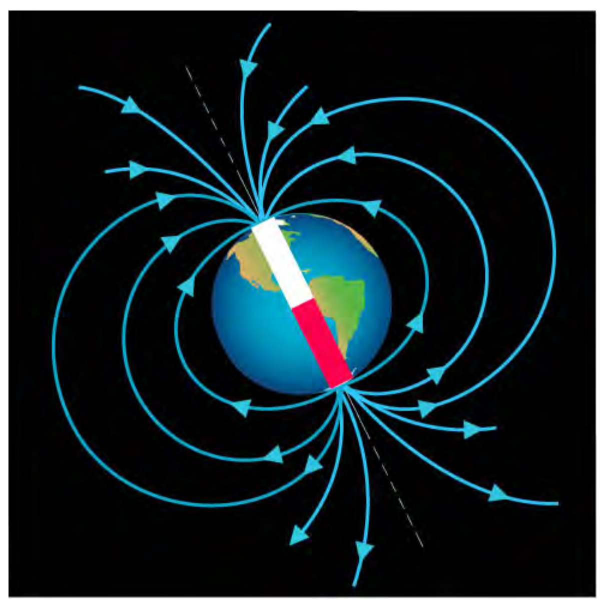
In a model with more than one magnet, the field lines are sometimes drawn connecting opposite poles on the magnets. These field lines help predict the direction of the forces pulling or pushing different magnets. A model showing field lines connecting the opposite poles of different magnets indicates that the magnets will be attracted together. A model showing two magnets that are not connected to each other by field lines indicates that the magnets will repel each other.



This model uses field lines to show what happens to the fields between two magnets. Opposite poles are attracted to each other, while poles of the same type are repelled away from each other.

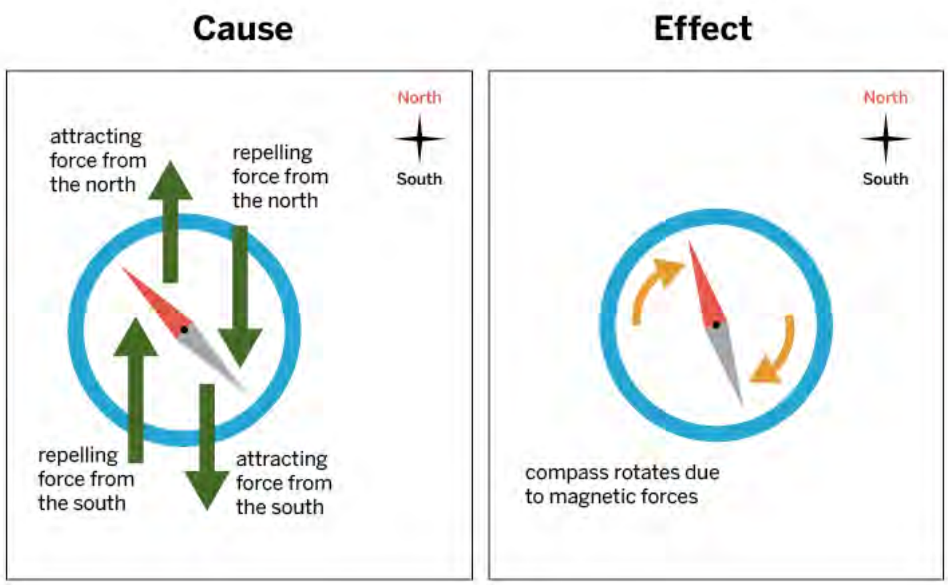
Compasses are helpful in determining which direction the magnetic field is going and where the field lines should be drawn. Field lines drawn to model Earth's magnetic forces are based on the directions compass needles point at different places on Earth. Compass needles spin so that one end points to the north pole. This happens because each geomagnetic pole attracts the opposite pole of the compass at the same time it repels the like pole of the compass. These magnetic forces cause the compass needle to rotate until it points north.

You can see the effect of Earth's magnetic field when you hold a compass in your hand—the needle points north, and knowing which way is north can help you find south, east, and west. Some animals can figure this out without looking at a compass. They have tiny bits of metal in their cells that act like tiny compass needles! These bits of metal rotate to point north, giving these animals a natural sense of which way is north. Animals like bees, bats, and some types of birds use this knowledge to find their way. Some use it for short distances, like bees that have flown away from their hives. Others, like snow geese, use it to migrate thousands of miles every year.



Earth's magnetic field lines point from the magnetic north pole to the magnetic south pole. Does something look weird? That's because Earth's magnetic poles are backwards! The place we call the North Pole is actually where you find Earth's magnetic south pole.

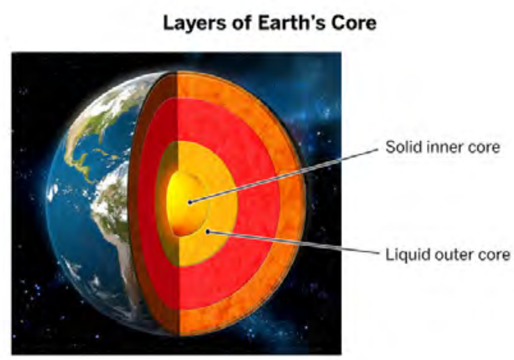
Earth acts like a giant bar magnet, with a north pole and a south pole that affect compass needles, but there isn't actually a bar magnet in the center of Earth. Earth's magnetic field is caused by the planet's liquid iron core moving



Each end of a compass needle is attracted by the magnetic force of one of Earth's magnetic poles and repelled by the other. Since the needle is attached to the compass in the middle and can't go anywhere, it spins in a circle.

around. The process that creates a planet-wide magnetic field is called geomagnetism.

It may seem amazing that forces produced in the center of Earth could act on objects so far away, but Earth's magnetic field actually reaches much farther than Earth's surface. These forces are acting on Earth all the time, and we use them for everything from navigation to sorting recycling. So although you can't see them, you interact with the forces of geomagnetism every day.



Earth has an inner core of solid iron surrounded by an outer core of liquid iron. Heat from the inner core causes the liquid iron to move, producing a magnetic field.

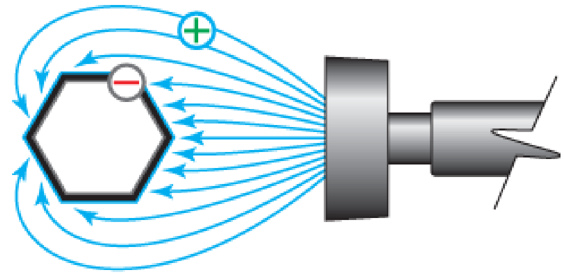
Spray-painting can be a messy job, but some people use static electricity to attract spray paint to the objects being painted.

Painting with Static Electricity

Have you ever spray-painted anything? If you have, you know that it can be messy—paint doesn't just end up on the object you're trying to paint. You might put down an old sheet or a big piece of plastic to protect the area from paint splatters, but even that might not catch everything. The tiny droplets of paint can end up on the ground and anything else that happens to be nearby . . . and if it's a windy day, they might not end up where you want them at all! Spray painting can also waste paint, since some of the paint in the can doesn't end up on the object you're painting. Some people avoid all these problems by using an electrostatic painting system. These painting systems use static electricity to make sure paint goes where you want it to and not where you don't.

Electrostatic painting systems use electric fields to guide paint in the right direction. Just as magnets produce magnetic fields, electric charges create electric fields—these two types of fields aren't the same, but they behave in many similar ways. Electric fields move objects without touching them, extend in all directions from the charges that produce them, and can be modeled with field lines, just like magnetic fields. Both electric fields and magnetic fields can produce attractive forces and repulsive forces. Electric charges can be positive or negative. If two charges are the same—both positive or both negative—the force between them is repulsive. If one charge is negative and one is positive, the force between them is attractive.

Electrostatic painting systems work because opposite electrical charges are attracted to one another. Painters charge the object they're painting with a negative charge, and the paint gets charged with a positive charge as it goes through the nozzle of the sprayer. Because they have opposite charges, the paint droplets are attracted to the object and go straight toward it. Droplets that are headed in the wrong direction will even change direction and move toward the object that's being painted! These systems make sure paint ends up where it's supposed to, and nowhere else.



Electrostatic paint systems work by charging the object that's being painted with a negative charge, then charging the paint with a positive charge. When the paint comes out of the nozzle, it's attracted to the object.

Using spring stilts, people can bounce very high and run very fast.

The Potential for Speed

Chapter 1: Introduction

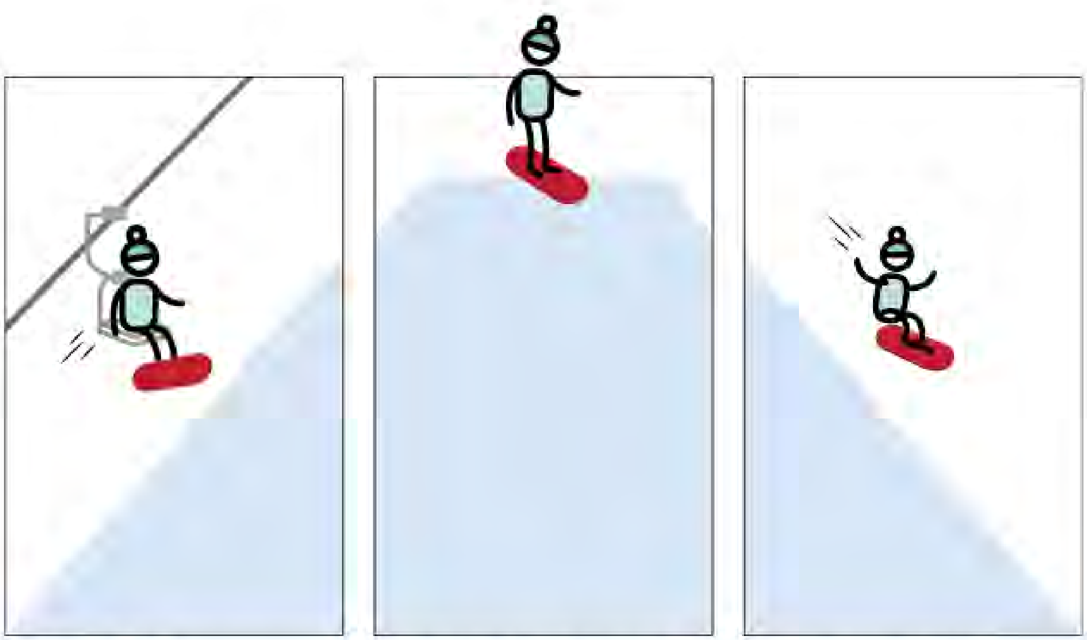
Can you fly through the air? Can you zoom down a snowy mountain at 80 kilometers per hour (50 miles per hour)? With a little extra equipment and some practice, you probably can: extreme sports allow us to do exhilarating things our bodies can't do on their own. To get the speed and height we like so much, these sports rely on two kinds of energy—kinetic energy, which is the energy of motion, and potential energy, which is stored energy. By adding a force to the mix, these two types of energy can be converted back and forth—motion energy can become stored energy, and stored energy can become motion energy. For extreme athletes, that conversion usually means speed, height, or both! To learn more about how energy and force make these exciting things possible, read one of the chapters that follow.

Chapter 2: Snowboarding

Launching off a ramp in the snow takes a lot of kinetic energy.

Is there any bigger thrill than weaving down a mountain on a snowboard? The world record for speed on a snowboard is a whopping 203 kilometers per hour (126 miles per hour), and advanced snowboarders regularly reach speeds of 65-70 kph (40-45 mph) to launch themselves high into the air off ramps in the snow. Going that fast requires a lot of kinetic energy. Kinetic energy can't appear out of nowhere, although it can be transferred or converted from a different form of energy. How do snowboarders get the kinetic energy they need to launch themselves into the air?

It's all about gravity. Gravity is a pulling force that can change the motion of an object. When Earth pulls objects toward itself with the force of gravity, it can transfer energy between the parts of systems. The snowboarder and Earth form a system. When the ski lift pushes the

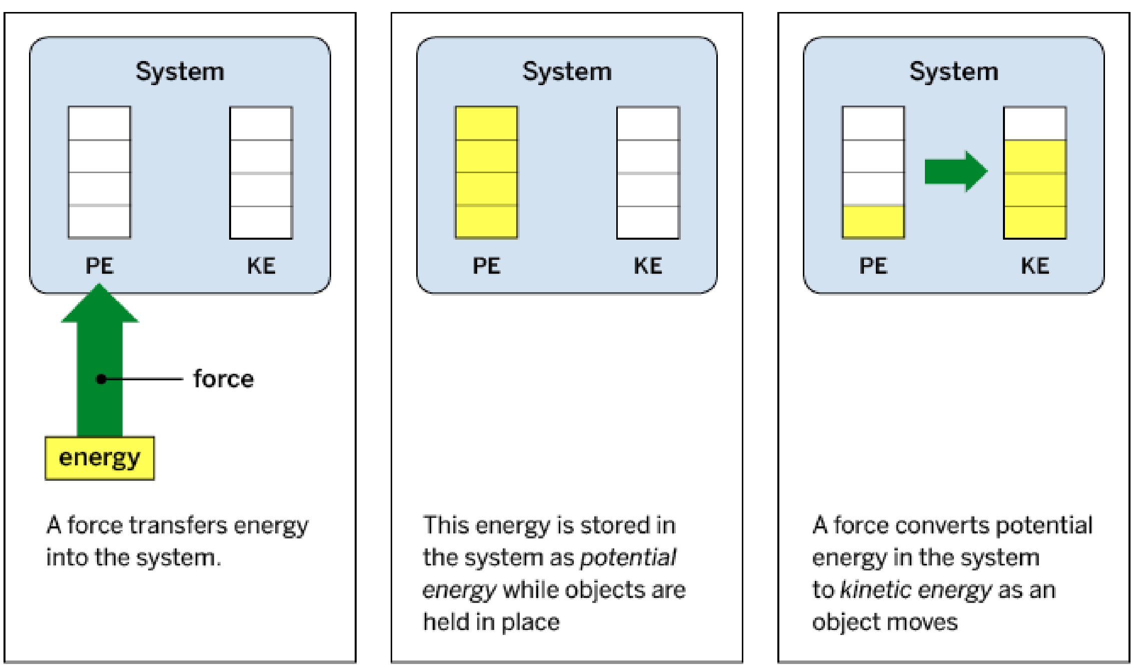


snowboarder to the top of the mountain, the ski lift is pushing against the force of gravity. The ski lift transfers energy into the snowboarder-Earth system, where it is stored as potential energy in that system. When the snowboarder starts going downhill, the force of gravity transfers this potential energy to the snowboarder and converts it to kinetic energy. As a result, the snowboarder goes faster and faster.

We say energy is stored in the system when the snowboarder is pushed away from Earth by the ski lift, but what does that actually mean? The system of Earth and the snowboarder is kind of like a rubber band. If you stretch a rubber band, the energy you're using to pull the rubber band apart is stored in the rubber band itself. When the rubber band snaps back to its unstretched shape, the stored energy is released. There is no invisible rubber band between a snowboarder and Earth, so where is the energy stored?

Earth and the snowboarder are connected by Earth's gravitational field, the space in which Earth can pull on objects at a distance. Even if we can't see the gravitational field, we can feel it—it's what keeps our feet on the ground and brings us back to Earth when we jump up and down. When the ski lift carries the snowboarder upward and away from Earth, potential energy is stored in the gravitational field between Earth and the snowboarder. When Earth pulls the snowboarder down the hill again, the force of gravity transfers potential energy from the gravitational field to the snowboarder in the form of kinetic energy. So reaching top speed on the mountain isn't just about great snow and a cool board. Without gravity, snowboarders wouldn't go anywhere!

How does force relate to potential and kinetic energy?

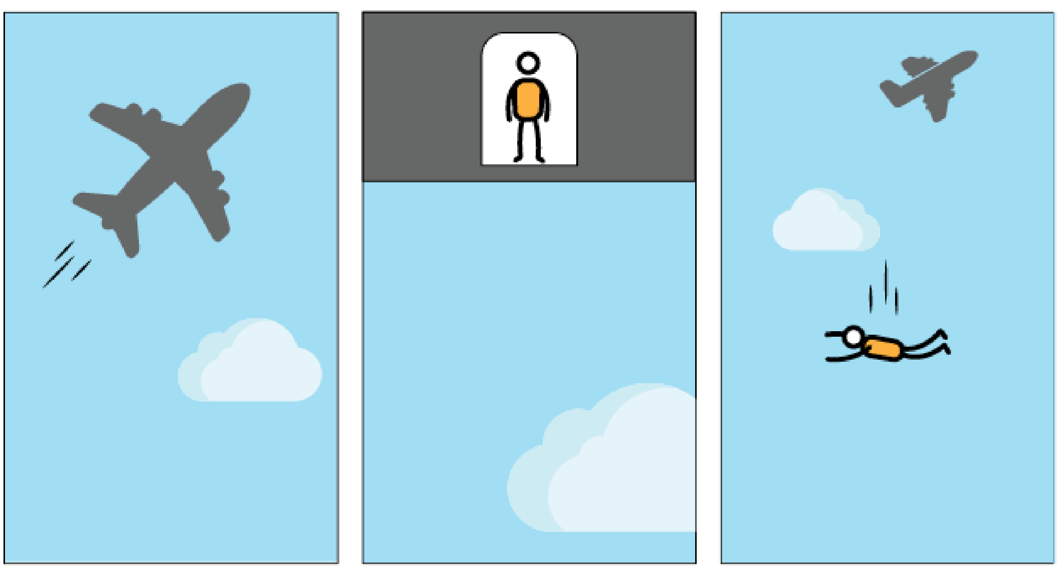


Skydivers can fall toward earth at speeds of up to 290 kph (180 mph).

Chapter 3: Skydiving

Would you ever jump out of an airplane thousands of feet above the ground? Skydivers looking for a thrill do it all the time! Skydivers start their dives from airplanes high above the ground and end up falling toward Earth's surface at speeds as high as 290 kilometers per hour (180 miles per hour). The skydivers aren't doing anything to make themselves go faster. So where do they get the kinetic energy to fall so quickly?

It's all about gravity. Gravity is a pulling force that can change the motion of an object and transfer energy into systems of objects. The skydiver and Earth form a system. When the airplane pushes the skydiver high into the sky, it pushes against the force of gravity and transfers energy into the skydiver-Earth system. That energy is stored as potential energy in that system. When the skydiver starts to fall toward Earth, the force of gravity transfers this potential energy to the skydiver and converts it to kinetic energy. As a result, the skydiver picks up a lot of speed.



force of airplane transfers potential energy into the Earth-skydiver system

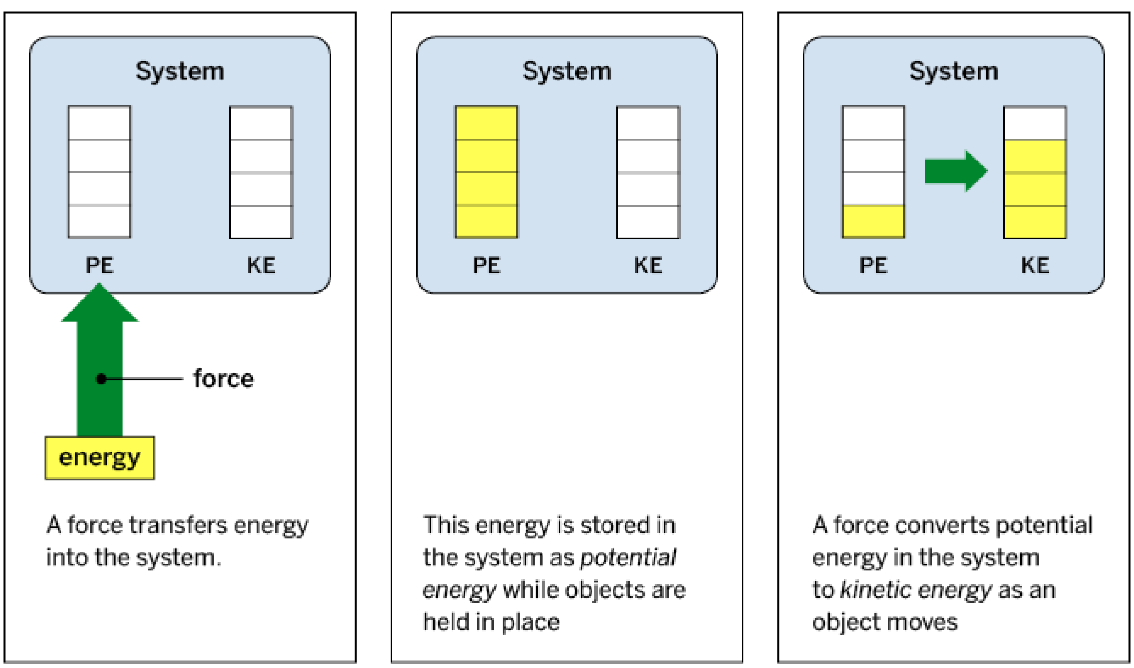
potential energy is stored in the gravitational field between the skydiver and Earth

the gravitational force converts potential energy into kinetic energy, giving the skydiver speed

What does it mean when we say energy is stored in the system of the skydiver and Earth? To understand this idea, it helps to think of the system as being like a rubber band. If you stretch a rubber band, the energy you're using to pull the rubber band apart is stored in the rubber band itself. When the rubber band snaps back to its unstretched shape, the stored energy is released. But there is no invisible rubber band between a skydiver and Earth, so where is the energy stored?

Between Earth and the skydiver is Earth's gravitational field, the space in which Earth can pull on objects from a distance. We can't see the gravitational field, but we can feel it in the form of a pull toward Earth. When the airplane carries the skydiver upward and away from Earth, potential energy is stored in the gravitational field between Earth and the skydiver. When Earth pulls the skydiver back down, the force of gravity transfers potential energy from the gravitational field to the skydiver and converts it into kinetic energy—that is, motion. Because the skydiver gains kinetic energy, he or she gains speed during the fall to Earth.

How does force relate to potential and kinetic energy?

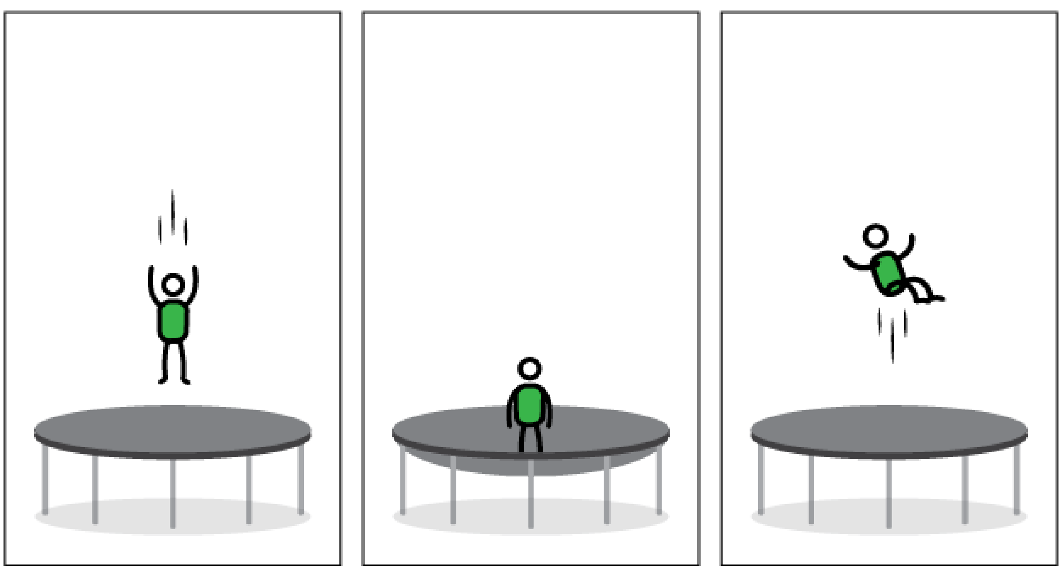


Chapter 4: Trampoline Gymnastics

Trampoline gymnasts have kinetic energy every time they bounce into the air.

If you've ever bounced on a trampoline, you know that you can bounce pretty high, especially if you bounce many times in a row. Did you know that some people use that power in competition? Trampoline gymnasts are athletes who use the speed and height gained from bouncing on a trampoline to do tricks that wouldn't be possible otherwise. Trampoline tricks require kinetic energy, or motion energy—and kinetic energy can't be created or destroyed. So if they start out standing still, where do trampoline gymnasts get the kinetic energy they need to bounce so high and so fast?

Bouncing on a trampoline involves a system made up of the gymnast and the trampoline. The trampoline has a certain shape, and it takes energy to change that shape. When the trampoline is stretched by a person



the force of the gymnast transfers energy into the trampoline-gymnast system

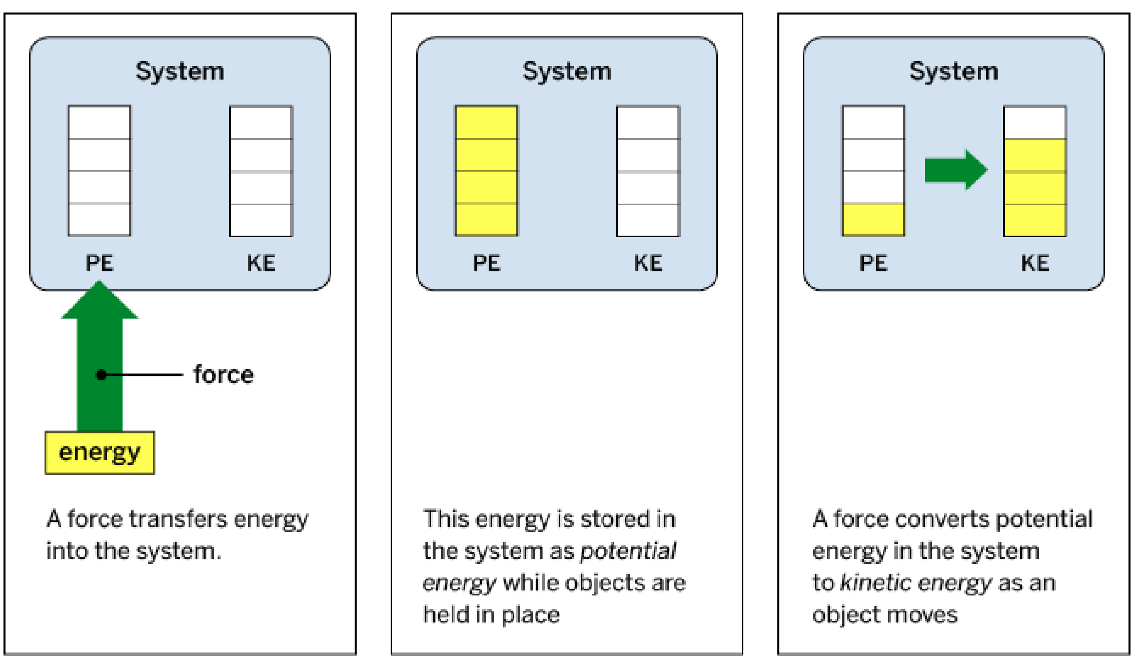
potential energy is stored in the system while the gymnast is touching the trampoline

the trampoline force converts potential energy into kinetic energy, giving the gymnast speed jumping on it, energy is stored in the system as potential energy. Then that energy is transferred to the gymnast in the form of kinetic energy, making him or her fly into the air.

So when a gymnast jumps on a trampoline, energy is transferred from one part of the system to another. How does energy get from the trampoline to the gymnast? It's all about force—a push or pull that can change the motion of an object and can transfer energy into systems. When the trampoline stretches, it responds by producing an upward force called elastic force on the gymnast, transferring potential energy to the gymnast and causing him or her to fly upward into the air. The gymnast's kinetic energy increases with every bounce and he or she travels higher and faster each time.

The trampoline transferred energy to the person. However, energy can't just be created, so the energy must have come from somewhere else. How did the trampoline get the energy in the first place? It came from the gymnast and was transferred into the system by a force! When the gymnast jumps on the trampoline, he or she pushes against the elastic force of the trampoline, which causes an energy transfer from the person to the system, and the energy is stored while the trampoline is stretched out of shape. Any kind of stored energy is called potential energy. When the trampoline snaps back to its natural shape, that potential energy transfers to the gymnast in the form of kinetic energy. That's why trampoline gymnasts fly so high!

How does force relate to potential and kinetic energy?

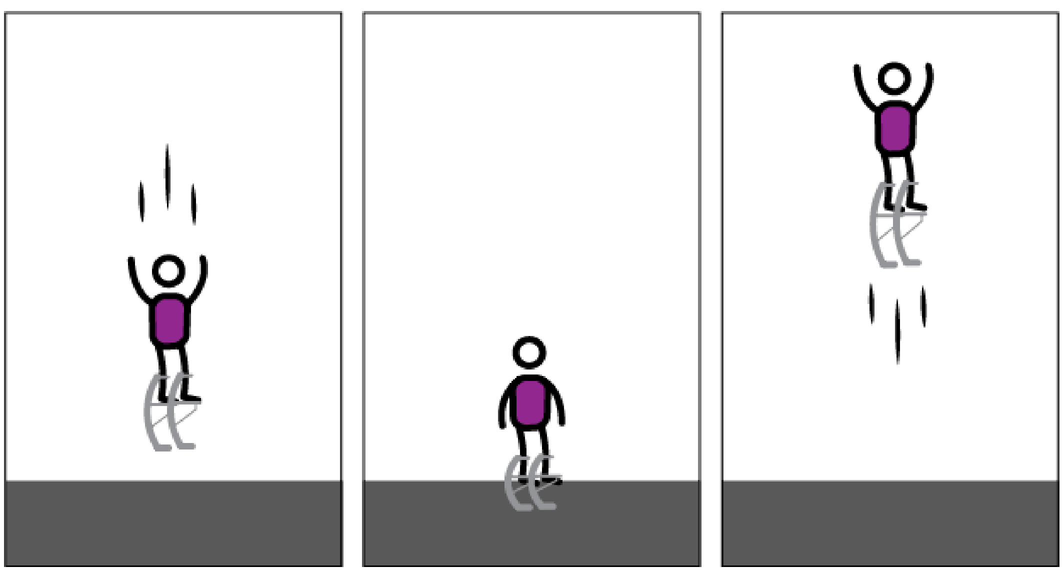


Chapter 5: Powerbocking

Using spring stilts, people can bounce very high and run very fast.

Wouldn't you like to be able to jump six feet in the air? Run as fast as a horse? Leap over a car? Well, you can—with a little bit of help. Spring stilts are like a cross between stilts and pogo sticks, and people use them to exercise and do tricks. With every step or jump, the person using the spring stilts gains kinetic energy, or motion energy, and goes a little bit higher. However, kinetic energy can't be created or destroyed, so that energy must have come from somewhere else. Where did it come from?

Together, the person and all the parts of the spring stilts form a system. The spring stilts have a certain shape, and it takes energy to change that shape. When the spring stilts are compressed, or squished—say, by a person stepping on them—energy is stored



the force of the jumper transfers energy into the jumper-spring system

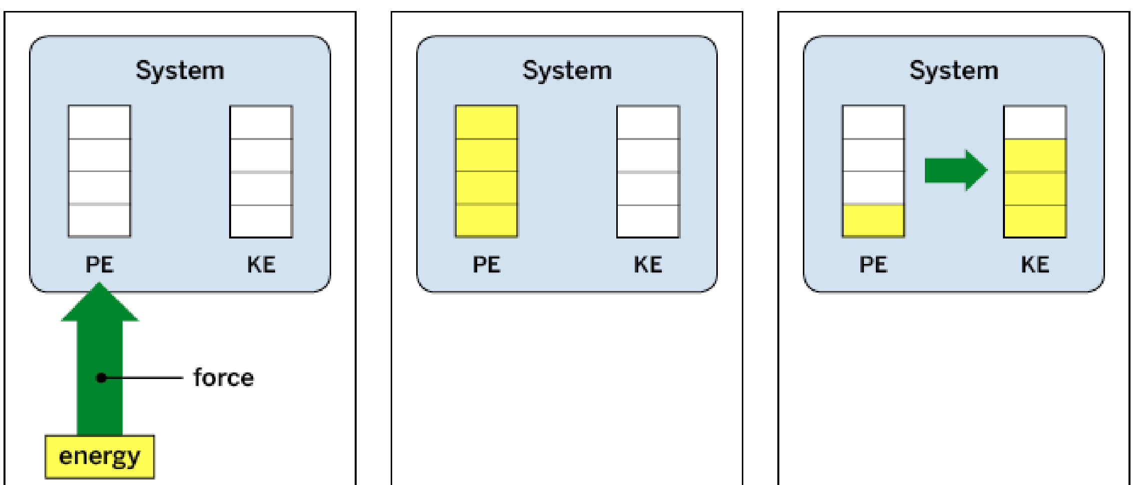
potential energy is stored in the system while the jumper pushes down on the stilts

the spring force converts potential energy into kinetic energy, giving the jumper speed in the system as potential energy. Then that energy can be transferred to the person in the form of kinetic energy, making him or her bounce forward or up into the air.

How does energy get from the spring stilts to the person? It happens through force—a push or pull that can change the motion of an object. When the coils in the spring stilts are squeezed together, they respond by producing a force called elastic force, transferring potential energy to the person and causing him or her to be pushed upward or forward. The person's kinetic energy increases with every bounce and he or she travels higher and faster each time.

The spring stilts transferred energy to the person. However, energy can't just be created, so the energy must have come from somewhere. How did the spring stilts get the energy in the first place? From the person using them! When the person steps onto the spring stilts, he or she applies a force to them. That force causes an energy transfer from the person to the system, and the energy is stored while the spring stilts are compressed. Any kind of stored energy is called potential energy. When the spring stilts return to their natural shape, that potential energy transfers to the person in the form of kinetic energy. That's how spring stilts help regular people move like superheroes!

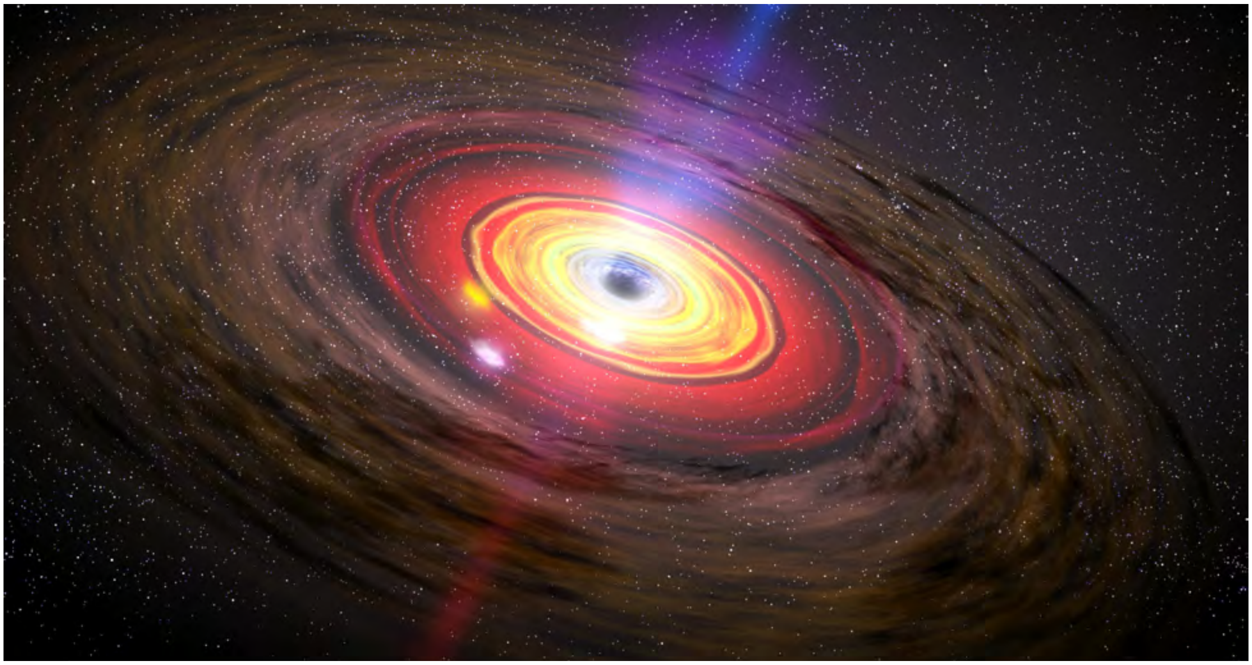
How does force relate to potential and kinetic energy?



A force transfers energy into the system.

This energy is stored in the system as *potential energy* while objects are held in place

A force converts potential energy in the system to *kinetic energy* as an object moves



An artist made this illustration of a black hole and the area surrounding it. Black holes themselves are invisible because no light can escape from them. However, the area around black holes may put out light.

Escaping a Black Hole

Imagine this: In far outer space, the crew of a spaceship encounters a black hole. They must use all their ship's power to escape, or they'll be sucked inside. Can they move quickly enough to get away? You might have seen or read something like this in a science fiction story. Black holes aren't science fiction, however—they really exist, although no human has ever gotten close to one! What are black holes, and what makes them so hard to escape?

Black holes are collapsed stars, and they're all about gravity. Gravity is an attractive force—that is, it pulls objects toward other objects instead of pushing them away. (You may have heard of "anti-gravity," but scientists have found no evidence that anti-gravity is a real force.) Gravity is a force between two objects; where there are no objects, there's no gravity.

The area around an object where it can exert gravitational force on other objects is called a gravitational field. The strength of an object's gravitational field depends on its mass: objects with small masses have weak gravitational fields and objects with large masses have strong gravitational fields. For example, Earth has a much larger mass than the Moon does, so it produces a much stronger gravitational field. That's why we are stuck securely to Earth when we walk, but astronauts on the Moon look like they're walking on springs. Like magnetic force and electrostatic force, the gravitational force between two objects also depends on how far apart they are: the closer the two objects, the stronger the field between them. A spaceship that got very close to a black hole would have no hope of escaping, but a spaceship that kept its distance might be able to pull away.

What does all this gravity talk have to do with black holes? When stars collapse to form black holes, a huge amount of mass is crammed into a very small area. Because the black hole has so much mass, it produces very strong gravitational force. Anything that gets within a certain distance is pulled toward the black hole. The closer the object gets, the stronger the force it experiences. At a certain point, the gravitational force of a black hole is so strong that nothing can escape—not even light. That's why black holes are black: light can't escape their strong gravitational force.

Magnetic Fields: Launching a Spacecraft

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

AMP.NA18
ISBN 978-1-947002-86-9

Amplify.

Published and Distributed by Amplify.
www.amplify.com