MOTION ENERGY

Grade 4 - Physical Science

TRAINER GUIDE

CONTENT AND PEDAGOGY
PROFESSIONAL DEVELOPMENT

Smithsonian
Science Education Center

The **Smithsonian Science Education Center** (SSEC) is an education organization within the Smithsonian Institution. The SSEC's mission is to transform K–12 *Education Through Science*™ in collaboration with communities across the globe. The SSEC promotes authentic, interactive, inquiry-based K–12 STEM teaching and learning; ensures diversity, equity, accessibility, and inclusion in K–12 STEM education; and advances STEM education for sustainable development. The SSEC achieves its goals by developing exemplary curriculum materials and digital resources; supporting the professional growth of K–12 teachers and school leaders; and conducting outreach programs through LASER (Leadership and Assistance for Science Education Reform) to help schools, school districts, state education agencies, and ministries of education throughout the world implement inquiry-based science education programs.

The **Smithsonian Institution** was created by an Act of Congress in 1846 "for the increase and diffusion of knowledge . . ." This independent federal establishment is the world's largest museum, education, and research complex and is responsible for public and scholarly activities, exhibitions, and research projects nationwide and overseas. Among the objectives of the Smithsonian is the application of its unique resources to enhance elementary and secondary education.

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Motion Energy

Grade 4—Physical Science

Trainer Guide

INTRODUCTION

In 2019, the US Department of Education awarded the Smithsonian Science Education Center an early-phase Education Innovation and Research (EIR) grant to support the development, implementation, and initial evaluation of evidence-based innovations to improve student achievement. The project, called Smithsonian Science for North and South Carolina Classrooms (PR# U411C190055), took place between October 2019 and September 2024 in third-, fourth-, and fifth-grade classrooms in North and South Carolina.

Between 2020 and 2023, participating teachers in implementation schools received curriculum professional development tied to two Smithsonian Science for the Classroom curriculum modules and content and pedagogy professional development tied to the content of each module to implement in their classrooms. The Center for Research in Educational Policy (CREP) at the University of Memphis evaluated the impact of these modules and professional development on student achievement using standardized assessments, classroom observations, and teacher focus groups.

This guide was developed as a support for trainers leading content and pedagogy professional development for fourth grade teachers implementing the Smithsonian Science for the Classroom Physical Science module *How Does Motion Energy Change in a Collision?*

HOW TO USE THIS TRAINER GUIDE

This guide shares important ideas and strategies for effectively delivering content and pedagogy professional development in connection with a Smithsonian Science for the Classroom module with educators. The professional development plan is outlined within a table on the following pages. The first column notes approximate timing for each activity and connections to standards or pedagogical strategies. The second column provides the trainer with additional directions in concise bullet points.

ROOM SETUP

To set up a classroom for this workshop:

- Move tables or desks so groups of three or four can work together.
- Locate the nearest restrooms and evacuation routes.
- Make sure speakers are working.
- Post a piece of chart paper labeled "Parking Lot" for participants to record questions and ideas for follow up later.
- Check the locations of power outlets and confirm how to access the Internet for online computer simulations.

WORKSHOP OVERVIEW

This trainer guide provides direction on facilitating the sessions highlighted in the table below.

Day 1		Day 2	
10:00 a.m.	Welcome Session	**10:00 a.m.**	Physical Science Content Session 2
11:00 a.m.	Misconceptions and Student Work	**12:00 p.m.**	Lunch
12:00 p.m.	Lunch	**12:45 p.m.**	Reflections
12:45 p.m.	Misconceptions and Student Work, continued	**1:30 p.m.**	Break
1:30 p.m.	Break	**1:45 p.m.**	Concurrent Sessions: Planning Ahead and Principal's Meeting
1:45 p.m.	Physical Science Content Session 1	**2:30 p.m.**	School Breakouts
3:45 p.m.	Wrap Up	**3:15 p.m.**	Closing Session
4:00 p.m.	Adjourn	**4:00 p.m.**	Adjourn

SCIENCE CONCEPTS AND STANDARDS

See Appendix 1 for the complete state standards listed here.

Sessions	Science Concepts	Standards

Day 1:
What Is Motion Energy?
	1.1. Forms of Energy
	There are different forms of energy, such as mechanical (motion), chemical, light (electromagnetic), sound, and heat (thermal) energy. Energy is transferred from one object to another object. Energy can be changed to a different form, which is called energy transformation. Energy transfer and transformation happen in a system, which has a boundary.
	• Forms of energy
	    • Light energy
	    • Sound energy
	    • Chemical energy
	• Concept of a system
	• Energy transfer
	• Energy transformation
	• Introduction of motion energy
		NC: 4.P.3, 4.P.3.1, 3.P.3
		SC: 4-PS3-2
		NGSS: 4-PS3-2

	1.2. Mechanical Energy Motion energy is also called mechanical energy, and there are two types of mechanical energy. Potential energy is stored energy due to the position or arrangement of an object. Kinetic energy is the energy of a moving object. Mechanical energy changes form continuously between potential energy and kinetic energy. The total energy of potential energy and kinetic energy is constant, which means energy is conserved. • PhET simulation: Energy Skate Park: Basics (Intro) • Potential energy (PE) • Kinetic energy (KE) • Conservation of energy (PE + KE)	**NC:** 4.P.3.1, 3.P.3, 5.P.1.1 **SC:** 4-PS3-1, 4-PS3-2 **NGSS:** 4-PS3-1, 4-PS3-2, MS-PS3-1, MS-PS3-2

<table>
<tr><td rowspan="2">Day 2:

Mechanical Energy in Collision</td><td>2.1. Friction and Deformation

When there is friction, mechanical energy is transformed into thermal energy. Friction happens when an object is in contact with another object. Friction also happens in the air, because air is matter. Mechanical energy can also be transformed into thermal energy when there is deformation.
PhET simulation: Energy Skate Park: Basics (Friction)
Friction and thermal energy
Friction on surfaces
Friction in the air
Deformation and thermal energy
Microperspective of molecules movement</td><td>NC: 3.P.3, 5.P.1.1, 5.P.1.2
SC: 4-PS3-3
NGSS: 4-PS3-2, 4-PS3-3, MS-PS3-2, MS-PS3-3, MS-PS3-4</td></tr>
<tr><td>2.2. Collision Lab

There are two types of collisions: elastic and inelastic. In an elastic collision, there is no loss of kinetic energy after the collision. In an inelastic collision, there is a loss of kinetic energy after the collision; that energy is transformed into other forms of energy, such as heat and sound. However, total energy of the system is conserved.
PhET simulation: Collision Lab
Elastic collisions and inelastic collisions
Conservation of energy</td><td>NC: 5.P.1.1, 5.P.1.2
SC: 4-PS3-3
NGSS: 4-PS3-3, MS-PS3-5</td></tr>
</table>

MISCONCEPTIONS AND STUDENT WORK

Throughout this professional development, the trainer leads the sessions as a facilitator (modeling the teacher role) with teachers acting as learners. Though the content is designed for adult learners, the practices used by the facilitator may be used with grades 3-5 students.

SESSION GOALS

- Identify common misconceptions in student work.
- Increase understanding of where misconceptions come from and grow.
- Categorize student misconceptions based on their origin and impact on student learning.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
Housekeeping and Introductions	20 minutes	• Chart paper
Reflections	10 minutes	• Chart paper
Conceptual Change	30 minutes	• *Good Thinking!* video
Lunch	45 minutes	
Misconception Identification	45 minutes	• Chart paper • Sticky notes • Colored dot stickers (5 colors) • Markers • "Misunderstanding Misconceptions" article

Timing	Key Points
Housekeeping and Introductions 20 minutes	**Introductions** Welcome participants to your session. Remind them that this professional learning workshop is meant to be an experience for adult learners to support their understanding of pedagogical content knowledge underlying a Smithsonian Science for the Classroom next page →

Timing	Key Points
	module. Educators may feel some discomfort as they are confronted with the limits of their own content understanding just as their students do. Reassure them that this is part of the learning process and that it may help them build empathy for the students in their classrooms. **Icebreaker Activity** Participants introduce themselves through an icebreaker activity. Ask each participant to share what they remember about the last time they were taught this subject. **Housekeeping** Preview the agenda. Verify the safety protocols in the classroom and locate the nearest restrooms, fire exit, and tornado shelter.
	Establish the Tone for the Day Divide participants into small groups and ask them to think about what they want to achieve today. What norms do they think will encourage a positive learning environment? Introduce group norm ideas: • Be brave • Be present • Ask questions • Be respectful Have each small group discuss the suggested norms and add to the whole group list of norms. Once everyone has added their ideas, ask if there are any changes, additions, or modifications that need to be made. Once the discussion is finished, this will be the social contract the group abides by for the next two days.
Reflections 10 minutes	Have participants turn to their shoulder partner and discuss their successes and challenges when teaching these units. Pairs can also discuss how they overcame challenges they faced. After partners have had time to talk, ask them to share their main points with the whole group. Record the main ideas on chart paper so everyone in the room can benefit from the shared learning.

<table>
<tr><th>Timing</th><th>Key Points</th></tr>
<tr><td>Conceptual Change
30 minutes</td><td>Ask participants to write down in their notebooks their ideas in response to the following questions:
How would you describe a scientific misconception?
How do you think student preconceptions can affect their understanding of new scientific concepts?
Introduce the Good Thinking! Conceptual Change video.
Good Thinking! is a video series created by the Smithsonian Science Education Center to support K–12 science educators through targeted short-format videos that explore common student ideas and misconceptions about a range of science topics such as energy, chemical reactions, and natural selection, as well as pedagogical subjects such as student motivation and the myth of left- and right-brained people.

Explain that the video we're about to watch is about conceptual change and explores the way students learn and develop new conceptual understanding, and shows how student misconceptions can be uncovered and addressed as part of effective learning.

Show Good Thinking! Conceptual Change (run time: 6:26) https://s.si.edu/4dfqcQS

Debrief the video by asking the participants to share how the video changed their definition of misconceptions and how preconceptions affect new learning. Have participants share anything else they found interesting or helpful.

Before ending the session, let participants know that in the next session they will have a chance to explore student work and identify misconceptions. If your group is small and you're done before lunch, introduce the Keeley framework to allow more time for exploring student work after lunch.</td></tr>
<tr><td>Lunch
45 minutes</td><td></td></tr>
</table>

Timing	Key Points
Keeley Framework 10 minutes	Hand out the "Misunderstanding Misconceptions" article by Page Keeley. In the article, Keeley introduces a loose framework of five types of misconceptions: conceptual misunderstanding, factual misunderstanding, naïve idea, vernacular misconceptions, and fragmentary knowledge. These different types represent a misconception based on where it comes from, how it is expressed, and what impact it has on continued learning. Understanding which type of misconception students have can assist in determining where the misconception is coming from and what the impact on learning might be.
Exploring Student Work 30 minutes	To help prepare for content sessions and future implementation, have table groups read student work and mark misconceptions with colored dot stickers, indicating which type from the framework they think the misconception falls into. Each misconception could be multiple categories in the framework.
Wrap Up 5 minutes	Ask participants to write misconceptions they found and their category from the framework on sticky notes and post them on a piece of chart paper. Let the group know they will revisit these ideas tomorrow after they have completed the content sessions.
Trainer Note: Possible Misconceptions	Some misconceptions participants may identify include: • The motion energy of an object does not depend on its speed. • Falling objects do not have motion energy. • Only people have energy. • Energy can be created and/or destroyed. • Energy can be transformed into a force. • Motion energy is used up as an object moves. • Gravitational potential energy is not dependent on height above ground. • Motion energy is not changed into heat. • An object doesn't have energy if no one is touching it. • Air is not matter.

CONTENT SESSION 1:

What Is Motion Energy?

SESSION GOALS

- Develop a conceptual understanding about energy and identify five main forms: motion, light, sound, heat, and chemical.
- Understand that energy is continually transferred from one object to another and transformed into its various possible forms within the system.
- Understand that motion energy is also called mechanical energy and that there are two types of motion energy: potential and kinetic.
- Understand that total energy is conserved in an isolated system.
- Run a computer simulation and observe the results when variables are changed.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
1.1 Forms of Energy	65 minutes	• Energy Card set • Scissors • Energy transfer and transformation diagram template • Images A, B, C • Chart paper (optional) • Glue stick or tape (optional) • Markers (optional)
1.2 Mechanical Energy	55 minutes	• Laptop for each group • Notebook Sheet A (Appendix 2) • Chart paper • Sticky notes (yellow and blue)

1.1 Forms of Energy

65 minutes

Timing	Key Points
Introduction 5 minutes	Introduce the topic and science concepts that will be covered in this section.
Forms of Energy 15 minutes	1. Show the pictures on the Energy Card set (the images show a running dog, a fire, an X-ray image, the sun in the sky, batteries, a plant, lightning, power plants, a boy singing, and a roller coaster) and ask: • What do you see in the picture? • What is similar about the pictures? Is there a common theme? (Yes, they are all about energy.) • What are the differences between the pictures? (They show different types of energy.) 2. Make small groups of two or three participants. Precut the Energy Cards or ask participants to cut out the cards. Ask participants to categorize the cards into similar energy types and name which energy the image(s) represent(s). Ask: • What types of energy do you recognize? (The answers may include motion energy, electric energy, light energy, sound energy, chemical energy, and heat energy). 3. Explain that there are various forms of energy: motion (mechanical) energy, heat (thermal) energy, light (electromagnetic) energy, sound energy, electrical energy, chemical energy, and more.
Energy and Systems 10 minutes	1. Ask the question, "What is energy?" Wait for responses and let participants share their thoughts freely. Then explain: • Energy is the ability to do work. • In a more sophisticated definition, energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. next page →

Timing	Key Points

	2. Ask the question, "What is a system?" Wait for responses and let participants *share* their thoughts freely. Then explain:
	• A system is a group of entities (called components) working together.
	• The components of a system interact or interrelate to one another.
	• A system has a boundary. (It is very important!)
	
	3. Emphasize that energy is the ability to do work within a system, which has a boundary.
	
	4. Explain light, sound, and chemical energy.
	• Light energy is called electromagnetic energy because the waves of energy have oscillating electric and magnetic fields.
	  ◦ Light energy is transferred as a form of radiation, which means it does not require a material as a medium for propagation. That is why light can travel in space.
	  ◦ Visible light is only a part of the spectrum of electromagnetic waves. Ultraviolet, X-rays, and gamma-rays have shorter wavelengths than visible light. Infrared, microwaves, and radio waves have longer wavelengths than visible light.
	  ◦ The shorter the wavelength, the higher the energy.
	• Sound energy is caused by vibration, which is movement in the surrounding air particles.
	  ◦ Particles in the air act as a medium to transmit the vibration.
	  ◦ If there is no medium (such as air), sound energy will not be transmitted.
	• Chemical energy is stored in the bonds of chemical compounds.
	  ◦ It is released during a chemical reaction, usually in the form of heat.
	  ◦ Examples are batteries, coal, plant photosynthesis, and our body's digestion.

Timing	Key Points
Energy Transfer and Transformation 25 minutes	1. Show the energy transfer and transformation diagram template from last year's professional development and explain: • Energy can be transferred from one object to another object. Energy can change into a different form, which is called energy transformation. • This energy transfer and transformation happens in a system. 2. Show the energy model template with the image of throwing a ball from last year's professional development and explain: • The object in the template represents a component of a system. • Evidence of energy in the template represents a form of energy. • Energy is transferred from the arm to the ball. • Energy is not transformed into a different form in this system because it's the same motion energy. 3. Show the image of a circuit (Figure 1) and ask what form of energy is involved in this system. Explain:

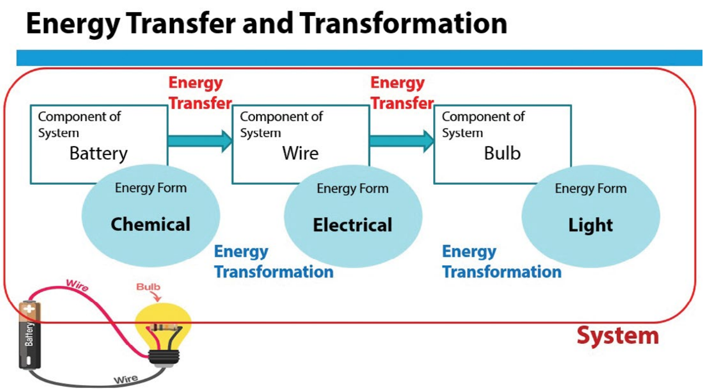


Figure 1. An example of energy transfer and transformation (credit: Smithsonian Science Education Center)

	• There are three components in the system and each component has a different form of energy: battery (chemical energy), wire (electrical energy), and bulb (light energy). next page →

Timing	Key Points
	• Energy is transferred to a different object (component), and the energy is transformed into a different form. • In the system, the components interact with one another within a boundary, which has no other source of energy added into the system. 4. Make small groups of two to three participants. Hand out Images A, B, and C. Image A shows a green field with cows eating grass and the sun is in the sky. Image B shows a woman exercising, with pictures of food. Image C shows the sun and a solar panel, with an image of an electric toaster plugged into the power. Ask participants to: • Observe each image. • Identify the components of a system and the system boundary, and how the components interact with one another within the system. • Find out which form of energy each component has and how the energy is transformed. • Draw the energy transfer and transformation diagram for each system. 5. Let each group share their thoughts in a whole-group discussion. • Image A: sun (light energy)—grass (chemical energy)—cow (chemical energy) • Image B: food (chemical energy)—human (chemical energy)—human (motion energy) • Image C: sun (light energy)—solar panel (electrical energy)—toaster (heat energy)
Mechanical Energy 10 minutes	1. Introduce the concept of motion energy, which is stored energy in moving objects. And ask participants to recall what concepts about motion energy were covered in the Smithsonian Science for the Classroom module: • A moving object has motion energy (Lesson 1). • Faster objects have more motion energy (Lesson 6). • Motion energy can change into heat, light, and sound (Lesson 3). next page →

Timing	Key Points
	• Motion energy can move to another object in a collision (Lesson 4). • Faster objects produce more sound in a collision (Lesson 5). • Speed and surface affect how far an object will slide in a collision (Lessons 14 and 15). • Motion energy changes to heat when an object slides on a surface (Lesson 8), when an object moves through the air (Lesson 9), and when a soft object deforms (Lesson 10). 2. Explain that motion energy is also called mechanical energy, and there are two types of mechanical energy: potential energy and kinetic energy. • Potential energy is stored energy due to the position or arrangement of an object. • Kinetic energy is the energy of a moving object. 3. Explain that mechanical energy changes form (in other words, it transforms) continuously between potential energy and kinetic energy. • Dropping an object (gravitational PE) • Nailing using a hammer (gravitational PE) • Pulling back a bowstring to shoot an arrow (elastic PE) • Newton's cradle (gravitational PE) 4. Explain that there are various types of potential energy, but we will focus on gravitational potential energy in this professional development. • Gravitational potential energy: energy stored by an object's mass and position in a gravitational field. • Elastic potential energy: stored energy of a spring or a rubber band that is stretched. • Magnetic potential energy: energy stored by a magnetic object's position in a magnetic field. • Electric potential energy: energy stored by the size of an electric charge and its position in an electric field.

1.2 Mechanical Energy

55 minutes

Timing	Key Points
Energy Skate Park (Intro) 50 minutes	1. Show a graph of kinetic and potential energy of a skater on a track and ask, "Where could she be on the track?" Collect the individual participants' responses. Afterwards, let them share their answers freely and briefly, but do not share the correct answer at this point. Tell them we will come back to this question at the end. 2. Have participants take out their laptops and let them know that we are going to work with a computer simulation (PhET simulation) called Energy Skate Park: Basics. https://phet.colorado.edu/en/simulations/energy-skate-park-basics • Have them click on the video simulation at the top of the page, choose Intro, and explore it freely for one or two minutes. • Explain that we should make sure we assume there is no friction in this simulation and throughout this activity. We will consider friction in the next section, but not today. 3. Small Group Activity (20 minutes) Hand out Notebook Sheet A (Appendix 2) to each person. Make groups of three or four participants and ask them to work on the notebook sheet as a small group. Allot 20 minutes for the notebook sheet activity. 4. Whole Group Discussion (20 minutes) After 20 minutes, go over the material as a whole group. Let participants share what they observed. • Q1. What is the difference between the two cases (when the skater is on the top of the ramp vs. in the middle of the ramp)? *When the skater is on the top she moves, but when she is in the middle of the ramp she does not move.* next page →

Timing	Key Points
	• Q2-1. What relationship do you observe between the location of the skater and the potential energy? *The higher she is, the higher the potential energy she has. Potential energy is proportional to height.* • Q2-2. What relationship do you observe between the mass of the skater and the potential energy? *The greater the mass of the skater, the higher the potential energy she has. Potential energy is proportional to mass.* • Q2-3. What can you learn about the height at which an object is located and the mass of an object, and its potential energy? *Potential energy is proportional to the height where an object is located and the mass of the object: PE* $\propto$ *height x mass* • Explain that potential energy is also proportional to the gravitational pull (acceleration of gravity), and all together it is written as a mathematical formula: PE = mgh. • Q3-1. What do you observe as the skater moves along the different heights of the ramp? *When the skater is moving along the ramp, the bar graphs of PE and KE change. When the PE is high, KE is low, and vice versa.* • Q3-2. What do you observe about the speed of the skater as she moves along the different heights of the ramp? *The speed of the skater is zero when she is on the top of the ramp, the speed increases as she gets close to the bottom of the ramp, and the speed decreases as she moves to the higher location on the ramp.* • Q3-3. What do you observe about the total energy as the skater moves along the different heights of the ramp? *Although the PE and KE transform into each other, the total energy is the same (conserved).* next page →

Timing	Key Points

	• Further explain that:
	  ◦ In this system, there is a skater on Earth, where Earth's gravity is pulling on the skater.
	  ◦ The potential energy of the skater is transformed into the kinetic energy of the skater, and vice versa in this system.
	  ◦ The total energy, which is the sum of potential and kinetic energy, is the same. In other words, the total energy is conserved.
	• Extension: For those who may be further interested in the transformation between potential energy and kinetic energy, explain how the speed is proportional to the square root of height. Ask the same concept question at the end and explain that the correct answer is D.

Reflection 5 minutes	1. Address any questions from the group. If you do not know the answer, put the question in the parking lot until you can look the question up. 2. Remind them that they will do digital simulations again tomorrow, so bring a laptop, if possible. Learner Reflection Wrap up the session by having a general conversation to debrief the session as learners. Ask questions such as: • Any questions about the content covered in the session? • What new learning did you encounter today? • What misconceptions did you debunk today? next page →

Timing	Key Points
	Teacher Reflection Wrap up the session by having a general conversation to debrief the session as teachers. Ask questions such as: • Where can you tie these concepts back to the curriculum module? Address content and practices. • Any misconceptions that teachers may expect from their students on the science concepts covered in the session? Exit Ticket Ask participants to record their "sunshines and blues" for the day on yellow (sunshines) and blue (blues) sticky notes and add them to a piece of chart paper before leaving for the day.

CONTENT SESSION 2:

Mechanical Energy in Collision

SESSION GOALS

- Develop conceptual understanding that mechanical energy is transformed into thermal energy when there is friction or deformation.
- Recognize a common misconception that friction is not energy, but is a force that resists motion when an object is in contact with another object.
- Understand the microperspective of molecular movements in friction and deformation using a visual representation.
- Explore elastic and inelastic collisions through a computer simulation.
- Run a computer simulation and observe what happens when you change variables.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
2.1 Friction and Deformation	50 minutes	• Stopwatch or timer for each group • Notebook Sheet B (Appendix 3) • Laptop for each group
2.2 Collision Lab	70 minutes	• Notebook Sheet C (Appendix 4) • Laptop for each group

2.1 Friction and Deformation

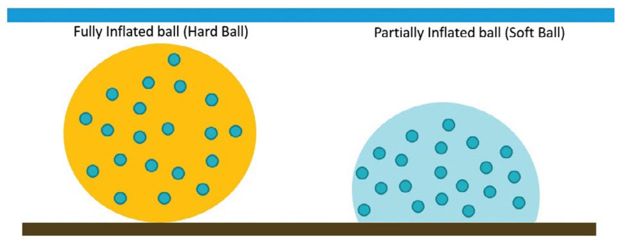
50 minutes

Timing	Key Points
Introduction 5 minutes	Introduce the topic and science concepts that will be covered in this section.
Energy Skate Park (Friction) 30 minutes	1. Start the session with a brief review of the previous session and tell participants that today we're going to talk about heat energy. next page →

Timing	Key Points
	2. Have participants take out their laptops and let them know that we are going to the Energy Skate Park: Basics PhET simulation again, but this time have them choose the "Friction" game: https://phet.colorado.edu/en/simulations/energy-skate-park-basics 3. Hand out Notebook Sheet B (Energy Skate Park Friction) to each person. Make groups of three to four participants and ask them to work on the notebook sheet as a small group. Remind them how to use a stopwatch. Allot 10 to 15 minutes for the notebook sheet activity. 4. When participants are done with the notebook sheet, go over the material as a whole group. Let participants share what they observed. • Q1. *The answers will vary by group, but medium friction will be around 24 seconds and high friction will be around 12 seconds.* • Q2. What do you observe from the activity? *Answers may vary. The higher the friction is, the faster the skater stops. As the friction increases there is more thermal energy produced, and the more mechanical energy is transformed into thermal energy. The thermal energy bar increases faster with higher friction.* • Q3. How does the total energy change? *The total energy does not change. It stays the same. The total energy is conserved*.
Friction and Thermal Energy 10 minutes	1. Explain: • It is a common misconception that friction is energy. • Friction itself is NOT energy. • Friction *creates* thermal energy. • Friction is a force that resists motion when an object is in contact with another object. next page →

Timing	Key Points
	2. Connect the concept of friction and thermal energy with the Smithsonian Science for the Classroom Grade 4 physical science module from last year's professional development. • Case A: Friction on surface (in Lesson 8) • Case B: Friction in the air (in Lesson 9) 3. Case A: In Lesson 8, there was an experiment to measure how far a washer moves when it is released from a ramp and it slides on different surfaces (wax paper, chart paper, and a mat). • When an object moves in one direction, friction happens in the other direction, resisting the object's movement. • This frictional force causes thermal energy in the system. • As the mechanical energy of the washer is transformed into thermal energy, the system has less mechanical energy, and it makes the washer slow down. 4. Case B: Lesson 9 introduced a cyclist wearing a smooth suit to reduce friction. Explain the concept that air is matter, from the G5 Engineering Intermediate professional development. • Air is matter. • Air is mostly gas (78% nitrogen, 21% oxygen) with tiny particles and dust, water vapor, and small amounts of other gases. • Air has mass, which means air has weight. • Show Figures 2 and 3 of the Space Shuttle that has stretch marks. These marks were created by air friction when the shuttle entered Earth's atmosphere. The mechanical energy of the shuttle was transformed into thermal energy by air friction and it slowed down the speed of the shuttle for landing. next page →

Timing	Key Points
	 *Figure 2. Space Shuttle displayed at the Smithsonian National Air and Space Museum Steven F. Udvar-Hazy Center (credit: Hyunju Lee, Smithsonian Science Education Center)*  *Figure 3. The heat shield tiles on the Space Shuttle show the stretch marks (credit: Hyunju Lee, Smithsonian Science Education Center)* 5. Ask participants to play the PhET simulation (or show it as a demonstration) that shows molecules in friction: https://phet.colorado.edu/sims/html/friction/latest/friction_en.html • Ask the whole group what they observed in the simulation. *When the book is rubbed, the molecules on the surface vibrate, creating heat.*
Deformation and Thermal Energy 5 minutes	1. Explain that mechanical energy is transformed into thermal energy when there is friction. Friction occurs on surfaces or in the air. There is also another case when motion energy is transformed into thermal energy, which is deformation. • Deformation was covered in Lesson 10 in the module. In Lesson 10, there was an activity experimenting with dropping a fully inflated ball and a partially inflated ball and measuring the different heights the two balls bounce. next page →

Timing	Key Points
	• Softer objects deform more than hard objects. And when an object deforms, some mechanical energy is transformed into thermal energy. 2. Explain how molecules move in deformation. When the ball is soft (partially inflated) it is more deformed, which results in the molecules inside the ball colliding with each other more frequently. **Movement of Molecules in Deformation**  *Figure 4. The image shows two balls, one fully inflated and the other partly inflated (credit: Smithsonian Science Education Center)* • When a ball is fully inflated, it is less deformed. The movement of molecules is less affected by the collision. • When the ball is soft or partially inflated, it is more deformed. The movement of molecules is more affected by the collision, and the movement gets much faster, so it creates more thermal energy. Since it creates more thermal energy, the ball has less kinetic energy to move, so it bounces less.

2.2 Collision Lab

70 minutes

Timing	Key Points
Elastic and Inelastic Collisions 10 minutes	1. Explain that the fully inflated (hard) ball and partially inflated (soft) ball actually represent elastic collision and inelastic collision. 2. Explain that elastic collision means no net loss in kinetic energy in the system as a result of the collision. • In other words, kinetic energy is conserved and there is no loss in speed after the collision. • Newton's cradle is a very close example of elastic collision. • However, in reality, there is no perfect elastic collision in our daily experience because in every collision small amounts of kinetic energy are transformed into other forms of energy, such as sound and heat. 3. Explain that inelastic collision has a loss in kinetic energy when objects collide. • In other words, some of the kinetic energy is transformed into other forms of energy, such as heat and sound. • Total energy in the system does not change. It is conserved (conservation of energy). next page →

<table>
<tr><th>Timing</th><th>Key Points</th></tr>
<tr><td></td><td>
4. Summarize elastic collision and inelastic collision.
<table>
<tr><th>Elastic Collision</th><th>Inelastic Collision</th></tr>
<tr><td>Conservation of Kinetic Energy</td><td>Some of kinetic energy is transformed to other forms of energy.
(The total energy is still conserved.)</td></tr>
<tr><td>No loss in speed after collision.</td><td>Loss in speed after collision.</td></tr>
<tr><td>$v_i = v_f$</td><td>$v_i \neq v_f$
$v_i > v_f$</td></tr>
<tr><td colspan="2">When there are two objects colliding each other</td></tr>
<tr><td>$KE_{object1,initial}$
$+ KE_{object2,initial}$
$= KE_{object1,final}$
$+ KE_{object2,final}$</td><td>$KE_{object1,initial}$
$+ KE_{object2,initial}$
$= KE_{object1,final}$
$+ KE_{object2,final}$
+ heat/sound (other forms of energy)</td></tr>
</table>
5. Remind participants that we had a marble collision activity in Lesson 4 of the Smithsonian Science for the Classroom Grade 4 physical science module from last year. Let them know that we are going to do a similar activity, but in a computer simulation today.
</td></tr>
<tr><td>Collision Lab
55 minutes</td><td>
1. Small Group Activity

Have participants take out their laptops and let them know we are going to work with the Collision Lab PhET simulation at this link: https://phet.colorado.edu/en/simulations/collision-lab
Click on the video simulation at the top of the page and choose the "Intro" game.
Explain that we will consider the collision of two balls moving in one-dimensional space (a line).

next page →
</td></tr>
</table>

Timing	Key Points

	• Ask them to select "Velocity" and "Kinetic Energy" in the box on the right, and select the "More Data" checkbox below the simulation. Explain that they can change "Elasticity" of the collision in the right-hand box.
	• Hand out Notebook Sheet C (Appendix 4) to each person. Make groups of three to four participants and ask them to work on the notebook sheet as a small group. Allot 40 minutes for the notebook sheet activity.
	
	2. Whole Group Discussion
	• Ask each group to share their results and what they found from the experiments.
	• Explain that in Q1:
	  ◦ When elasticity was 100%, balls did not lose velocity and total kinetic energy was the same (elastic collision).
	  ◦ When elasticity was 50%, balls lost velocity and there was a loss in total kinetic energy, which was transformed into other forms of energy (inelastic collision).
	• Explain that in Q2:
	  ◦ Elastic Collision (A & B): There was no loss in kinetic energy after the collision. It was the same. Especially when the masses were the same, each ball's velocity was transferred to the other after the collision.
	  ◦ Inelastic Collision (C & D): There was a loss in kinetic energy after the collision.
	• Explain that in Q3:
	  ◦ This experiment showed that kinetic energy did not change in the case of elastic collision, but kinetic energy decreased in the case of inelastic collision. We can learn from the simulation that some of the kinetic energy was transformed into other forms of energy, such as heat and sound, in the inelastic collision. The lower the elasticity, the more kinetic energy is transformed into other forms of energy. This is similar to what we learned earlier about friction.
	
	next page →

<table>
<tr><th>Timing</th><th>Key Points</th></tr>
<tr><td></td><td>In summary:
When there is an elastic collision, there is no loss in kinetic energy after the collision.
When there is an inelastic collision, there is a loss in kinetic energy after the collision, which is transformed into other forms of energy, such as heat and sound. The total energy of the system is conserved.</td></tr>
<tr><td>Reflection
5 minutes</td><td>Address any questions from the group. If you do not know the answer, put the question in the parking lot until you can look the question up.

Learner Reflection
Wrap up the session by having a general conversation to debrief the session as learners. Ask questions such as:
Any questions about the content covered in the session?
What new learning did you encounter today?
What misconceptions did you debunk today?
Teacher Reflection
Wrap up the session by having a general conversation to debrief the session as teachers. Ask questions such as:
How confident are you feeling about the science concepts underlying the module How Does Motion Energy Change in a Collision?
Where can you tie these concepts back to the curriculum module? Address content and practices.
Any misconceptions that teachers may expect from their students on the science concepts covered in the session?
Any other general questions?</td></tr>
</table>

REFLECTIONS

Before this session, consolidate the misconceptions from the first day into a number appropriate for your group.

SESSION GOALS

- Identify common misconceptions in student work.
- Increase understanding of where misconceptions come from and grow.
- Categorize student misconceptions based on their origin and impact on student learning.

Timing	Key Points
Addressing Misconceptions 30 minutes	1. Refer back to the misconceptions that were collected in the first session. 2. Break into small groups and have each group select a misconception to work on. 3. Give the groups time to discuss the misconceptions, what factors are part of the misconception, and how they might address it in the classroom, based on their experiences during the content sessions or other resources they may have access to. Ideally, groups are leveraging activities from their Smithsonian Science for the Classroom modules. 4. Have groups share out.
Grade Level Planning 15 minutes	Discuss what the next school year looks like, including when teachers might implement the lessons, what testing is upcoming, if there are any interesting resources available, etc.
Exit Ticket	Ask participants to record their “sunshines and blues” for the day on yellow (sunshines) and blue (blues) sticky notes and add them to a piece of chart paper before leaving for the day.

APPENDIX 1: SCIENCE STANDARDS

NORTH CAROLINA SCIENCE ESSENTIAL STANDARDS

4.P.3 Recognize that energy takes various forms that may be grouped based on their interaction with matter.

4.P.3.1 Recognize the basic forms of energy (light, sound, heat, electrical, and magnetic) as the ability to cause motion or create change.

3.P.3 Recognize how energy can be transferred from one object to another.

5.P.1.1 Explain how factors such as gravity, friction, and change in mass affect the motion of objects.

5.P.1.2 Infer the motion of objects in terms of how far they travel in a certain amount of time and the direction in which they travel.

SOUTH CAROLINA COLLEGE- AND CAREER-READY SCIENCE STANDARDS 2021

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

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

MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-PS3-4 Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

MS-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

APPENDIX 2: NOTEBOOK SHEET A

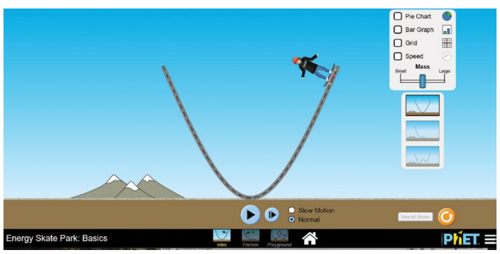
PHET SIMULATION: ENERGY SKATE PARK—INTRO

Energy Skate Park: Basics https://phet.colorado.edu/en/simulations/energy-skate-park-basics. Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (https://phet.colorado.edu).

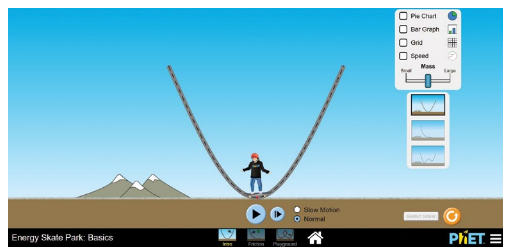
Please note that we do NOT consider friction in this Intro game.

1. In **Energy Skate Park: Basics**, click on the video simulation at the top of the page and choose the first option, **Intro**. Explore the simulation by placing the skater at different locations on the ramp and discuss the following questions in a small group.

   1-1. Place the skater on top of the ramp and play the simulation. What happens?

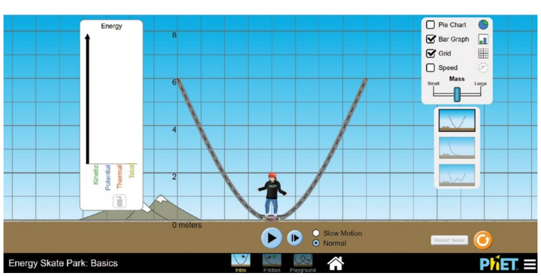
   1-2. Place the skater in the middle of the ramp and play the simulation. What happens?

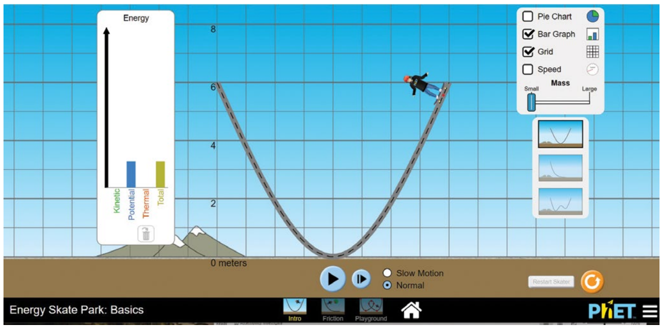
   1-3. What is the difference between cases 1-1 and 1-2? Why do you think that happens?

2. Click "Bar Graph" and "Grid" in the box on the right.

   2-1. Place the skater at different heights on the ramp (do not run the simulation yet). What relationship do you observe between the location of the skater and the potential energy?

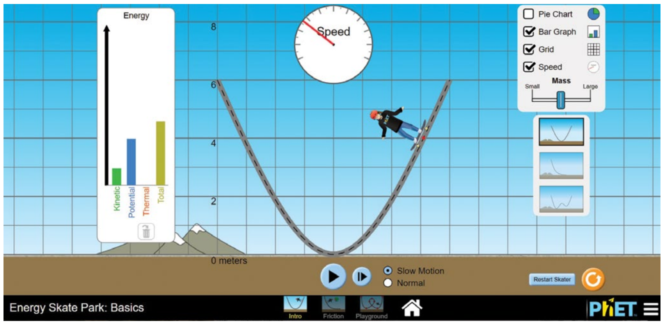
   

2-2. Now place the skater on top of the ramp. Change the skater's mass in the box on the right to the maximum, then to the minimum (do not run the simulation yet). What relationship do you observe between the mass of the skater and the potential energy?



2-3. What can you learn from activity 2-1 and 2-2 about the height at which an object is located and the mass of an object, and its potential energy?

3. Click "Bar Graph," "Grid," and "Speed" in the box on the right. Choose the "Slow Motion" option on the bottom. Run the simulation.



3-1. What do you observe between the bar graphs of potential energy and kinetic energy as the skater moves along the different heights of the ramp?

3-2. What do you observe about the speed of the skater as she moves along the different heights of the ramp?

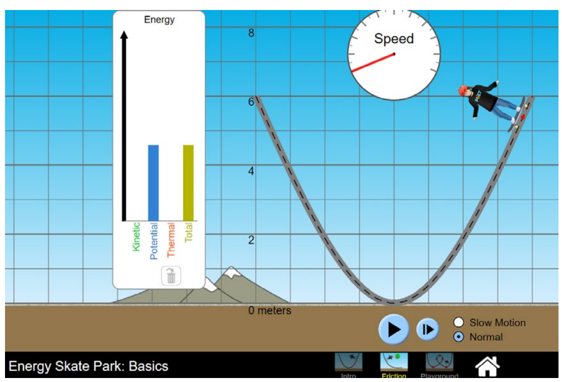
3-3. What do you observe about the bar graph of the total energy as the skater moves along the different heights of the ramp?

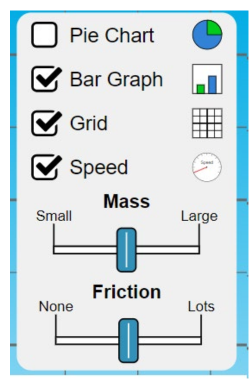
APPENDIX 3: NOTEBOOK SHEET B

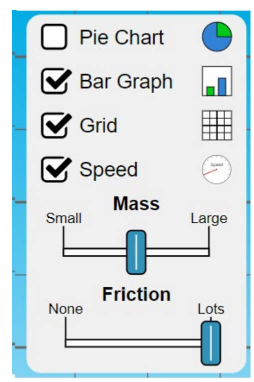
PHET SIMULATION: ENERGY SKATE PARK—FRICTION

Energy Skate Park: Basics https://phet.colorado.edu/en/simulations/energy-skate-park-basics. Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (https://phet.colorado.edu).

1. In **Energy Skate Park: Basics**, click on the video simulation at the top of the page and choose the second option, **Friction**. Click "Bar Graph," "Grid," and "Speed" in the box on the right. Set "Mass" in the middle. Set "Friction" to medium or high in the scale, as shown here, and place the skater on top of the ramp. Run the simulation and measure the time until the skater stops moving. Measure three times and record those times in the table.







Time Until the Skater Stops	Medium Friction	High Friction
Record 1		
Record 2		
Record 3		

2. What did you observe from this activity?

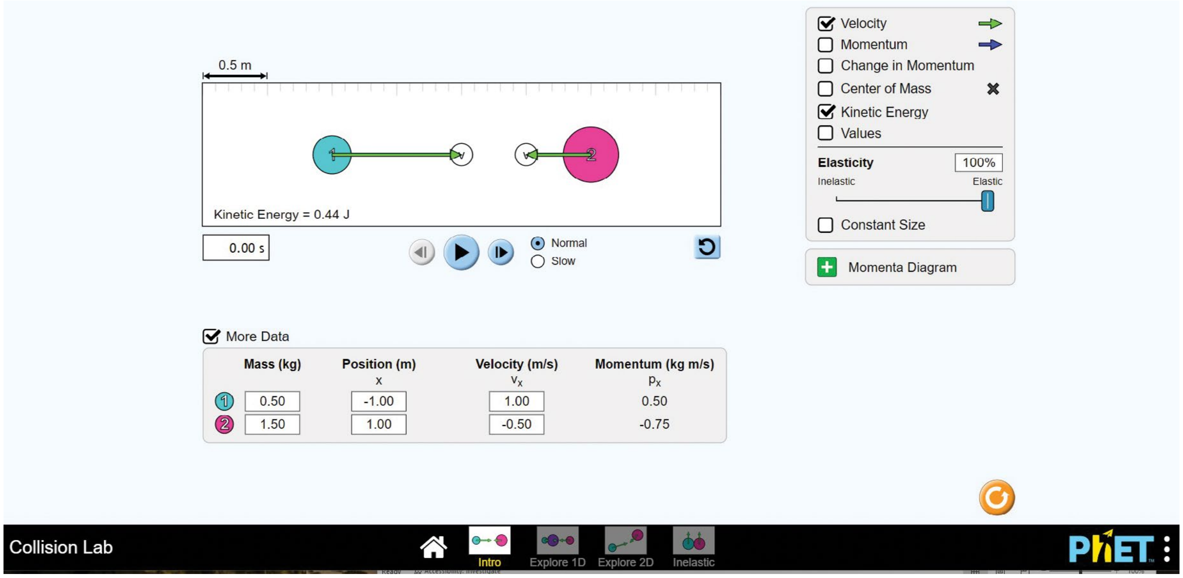
3. How did the total energy change? What did you learn from this?

APPENDIX 4: NOTEBOOK SHEET C

PHET SIMULATION: COLLISION LAB

Collision Lab: https://phet.colorado.edu/en/simulations/collision-lab. Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (https://phet.colorado.edu).

In **Collision Lab**, click on the video simulation at the top of the page and choose the first game, **Intro**. In this game, we consider balls move on only one dimension. Click “Velocity” and “Kinetic Energy” in the box on the right. Set “Elasticity” at 100%. Below the simulation, select “More Data” to open a box to enter more data. Please check that the position of ball 1 is set at -1.0 and ball 2 at 1.0.



Once these are checked, you are ready to begin the simulation!
When you want to retry at the same setting, click the small blue arrow button. If you click the orange arrow button on the far bottom right, the simulation will be reset to default.

Now, let’s do the simulation. Please set the simulation as indicated for each question before you run it.

1. Set ball 1's mass as 1.00, position as -1.00, and velocity as 0.50. And set ball 2's mass as 1.00, position as 1.00, and velocity as -0.50. The negative sign in the velocity means a different direction. (A positive number in velocity means a ball moves to the right. A negative number in velocity means a ball moves to the left.) Run the simulation by changing "Elasticity" in the right box to 100%, then 50%, and observe the balls' movement. (Note: Make sure to always set the position of ball 1 at -1.0 and ball 2 at 1.0.)

☑ More Data

	Mass (kg)	Position (m) x	Velocity (m/s) v_x	Momentum (kg m/s) p_x
1	1.00	-1.00	0.50	0.50
2	1.00	1.00	-0.50	-0.50

1-1. What is the velocity of each ball after collision, and what is the kinetic energy of the system? Fill in the table based on the simulation's results.

When Elasticity Is	Velocity (m/s)				Total Kinetic Energy (Joule)	
	Before Collision		After Collision		Before Collision	After Collision
	Ball 1 (1kg)	Ball 2 (1kg)	Ball 1 (1kg)	Ball 2 (1kg)	Ball 1 + Ball 2	Ball 1 + Ball 2
100%	0.50	-0.50			0.25 J	
50%	0.50	-0.50			0.25 J	

1-2. What did you observe from the activity? Describe the motion of the balls.

1-3. How much kinetic energy was lost when elasticity was 100% vs. 50%? What did you learn from this?

2. Let's experiment with the simulation for various cases. Discuss first what is going to happen for each case, before running the simulation. Run the simulation and record the velocity and total kinetic energy after the collision. Describe how the motion of the balls changed after the collision. (Note: Make sure to always set the position of ball 1 at -1.0 and ball 2 at 1.0)

2-1. **Elastic Collision** (set Elasticity = 100%)

Case	Mass (kg)		Velocity (m/s) Before Collision		Velocity (m/s) After Collision		Total Kinetic Energy (Joule)		Difference of Kinetic Energy
	m1	m2	$v1_{before}$	$v2_{before}$	$v1_{after}$	$v2_{after}$	KE_{before}	KE_{after}	$KE_{before} - KE_{after}$
A	2	2	0.5	-1			1.25		
B	1	2	0	-1			1		

2-2. **Inelastic Collision** (set Elasticity = 50%)

Case	Mass (kg)		Velocity (m/s) Before Collision		Velocity (m/s) After Collision		Total Kinetic Energy (Joule)		Difference of Kinetic Energy
	m1	m2	$v1_{before}$	$v2_{before}$	$v1_{after}$	$v2_{after}$	KE_{before}	KE_{after}	$KE_{before} - KE_{after}$
C	2	2	0.5	-1			1.25		
D	1	2	0	-1			1		

2-3. What did you find about kinetic energy for elastic collisions (A & B)?

2-4. What did you find about kinetic energy for inelastic collisions (C & D)?

3. What did you see as the difference between an elastic collision and an inelastic collision? What did you learn from this?

REFERENCES

Keeley, Page. (2012). Misunderstanding misconceptions. *Science Scope*, *35*(8), 12-15. Retrieved from https://static1.squarespace.com/static/5f09c80930b545063d089cc6/t/6170b127b00027733b5f07fc/1634775336010/Misunderstanding+Misconceptions.pdf

National Research Council (2008). *Ready, Set, SCIENCE!: Putting Research to Work in K-8 Science Classrooms.* Washington, D.C.: The National Academies Press. https://doi.org/10.17226/11882

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