Investigation 1 – What is happening when a spark occurs?

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INVESTIGATION 1: What is happening when a spark occurs?

Overview

The purpose of this investigation is to define energy. Before they are introduced to the concept of energy, students observe sparks from the Van de Graaff generator and discuss the model of matter that they have developed so far. At this point, the student model includes the rules for how charged objects interact, that charges interact through a field, and that atoms can be used to explain where charges come from. However, none of this explains why a spark forms. Once students recognize that their model is missing something, energy is discussed. In this investigation, two important aspects of energy are introduced: the concept of energy is useful for keeping track of changes, and it is useful to think of energy as an accounting system. At the end of the investigation, students identify that energy can be associated with motion or stored as potential energy. In the next investigation, students will define factors that affect how much potential energy is stored in a system. Through these investigations, students are developing a model of energy, which they can apply at the macroscopic and microscopic level, that includes kinetic and potential energy, transformations between these two kinds of energy, energy transfer, and conservation of energy.

The Performance Expectations (NGSS)

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.

Overview

Elements from NGSS (NGSS Lead States, 2013, p. 217-218)	**Connections to this investigation**
Elements of Disciplinary Core Idea	
Elements of the core idea from the NGSS Performance Expectation	How this investigation builds toward the core ideas
Conservation of energy and energy transfer: • When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.	Students should be able to use the ideas of energy transfer and conservation of energy to track changes in kinetic energy when objects interact. In this investigation, students make observations of colliding balls and simulations that display the kinetic energy of the objects represented in the model of energy they are constructing. Students are also introduced to using bar graphs to represent the amount of energy associated with different objects before and after interactions. Students use this information to build a model of energy that they use to track the kinetic energy of objects when they interact.
Crosscutting concept	
Crosscutting concept from the NGSS Performance Expectation	How this investigation builds toward the crosscutting concept
Energy and matter: • Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).	Energy can manifest in different forms: energy associated with motion is called kinetic energy, energy associated with the position of objects within fields is called potential energy. Students start by exploring the kinetic energy of moving objects. They are then introduced to the idea of conservation of energy (energy can change forms and transfer from one object to another but is not created or destroyed). Students use this concept to explore potential energy, energy conversion and energy transfer.
Science and engineering practice	
Science and engineering practice from the NGSS Performance Expectation	How this investigation builds toward the science and engineering practice

Engaging in argument from evidence: • Engaging in argument from evidence in 6-8 builds on K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). ○ Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.	This investigation focuses on developing and using models. Models are an important tool for supporting and communicating arguments based on evidence. Students also engage in asking questions. Asking sound scientific questions supports constructing scientific arguments because it is necessary to have a question to answer in order to engage in a scientific argument.

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance[1] when thermal energy is added or removed.

Elements from NGSS (NGSS Lead States, 2013, p. 56-57)	**Connections to this investigation**
Elements of Disciplinary Core Idea	
Elements of the core idea from the NGSS Performance Expectation	How this investigation builds toward the core ideas
Structure and properties of matter: • Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. • In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. • The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.	This investigation builds on the models of matter that students developed earlier. In this investigation, students use evidence to develop a relationship between temperature of solutions and observations that could be explained using a model of particle motion. At this point, thermal energy is discussed as simply the kinetic energy of particles. This prepares students to learn about thermal energy later. In Unit 3, students will add states of matter to this model.
Crosscutting concept	
Crosscutting concept from the NGSS Performance Expectation	How this investigation builds toward the crosscutting concept

[1] Gray text indicates aspects of a Performance Expectation that are not directly addressed in these materials.

Cause and effect: • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.	In this investigation, students apply cause and effect to developing and using models. Students also use the cross-cutting concept of energy and matter as a lens for explaining observations of phenomena.
Science and engineering practice	
Science and engineering practice from the NGSS Performance Expectation	How this investigation builds toward the science and engineering practice
Developing and using models: • Modeling in 6-8 builds on K-5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. ○ Develop a model to predict and/or describe phenomena.	This middle school PE is included in this introductory investigation because students need to develop the DCIs to study energy. Students' models should reflect high school modeling elements. In this investigation, students are asked to evaluate simulations (a form of models) and develop their own models to explain their observations of phenomena.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

Elements from NGSS (NGSS Lead States, 2013, p. 97-98)	**Connections to this investigation**
Elements of Disciplinary Core Idea	
Elements of the core idea from the NGSS Performance Expectation	How this investigation builds toward the core ideas

Overview

Definitions of energy: • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	In this investigation, students develop a model of kinetic energy, energy transfers, and conservation of energy. Students analyze evidence to relate kinetic energy to the motion of objects and particles. At the end of the investigation, students identify a need to define a different type of energy in order to consistently apply the law of conservation of energy. This prepares students for the next investigation, in which they will develop a model of potential energy that is based on the relative position of particles.
Crosscutting concept	
Crosscutting concept from the NGSS Performance Expectation	How this investigation builds toward the crosscutting concept
Energy and matter: • Energy cannot be created or destroyed--it only moves between one place and another place, between objects and/or fields, or between systems.	In this investigation, students use the lens of energy to build on their earlier model of matter and to explain additional observations.
Science and engineering practice	
Science and engineering practice from the NGSS Performance Expectation	How this investigation builds toward the science and engineering practice
Developing and using models: • Modeling in 9-12 builds on K-8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). ○ Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	Throughout this investigation, students evaluate simulations (a form of models) and develop their own models to explain observations of phenomena.

Target Model: *What should the students' conceptual model include?*

- *Energy is useful to track changes in systems.*
- *The model of energy should include the following:*
    - *Energy transfer*
    - *Energy conversion*
    - *Conservation of energy*
    - *The idea that energy is either associated with motion (kinetic energy) or stored (potential energy)*

Background Knowledge

Students often think that different types or forms of energy are completely different. However, energy should be a unifying idea, so students understand that there is only one entity called energy. This one entity can be observed in various ways, but that does not make these variations completely different entities. Energy can be thought of as an accounting system that is useful for keeping track of what happens during changes. In addition, energy can be associated with movement. Objects do not move forever, though, so in order for the accounting to balance, there must be a form energy can take that is not associated with movement. This form is stored, or potential, energy. Therefore, energy either is associated with motion or is stored. Depending on how it is stored or what type of motion is involved, energy may have different names. For example, gravitational potential energy is stored in a gravitational field, electric potential energy is stored in an electric field, and kinetic energy is the energy of movement. An object can have both kinetic energy associated with the overall movement of the object and thermal energy, which is related to the random motion of its atoms. . Energy can also be transferred. Light, sound, and heat are indicators that energy is being transferred.

Activities

Activity 1.1	*Can my finger start a fire?*	*45 min.*
Activity 1.2	*What happens to energy when objects collide?*	*180 min.*
Activity 1.3	*If moving objects have kinetic energy, do moving atoms have kinetic energy?*	*45 min.*
Activity 1.4	*If energy cannot go away, why don't things move forever?*	*45 min.*

Activity 1.1: Can my finger start a fire?

SUMMARY

The purpose of this activity is to introduce students to the driving questions for the unit and the investigation. Students note that their model of atoms and charges cannot explain sparks or how a spark starts a fire. This provides a motivation for adding energy to their current model of charges.

LEARNING GOAL

Students will ask questions about how their current model of electric charge explains their observations of sparks and ignition of flames, leading them to consider what might be missing from their model of charge.

Disciplinary core idea	**Crosscutting concept**	**Science and engineering practice**
In this activity students will explore phenomena that are related to the DCIs of *Energy: Definitions of energy (NGSS Lead States, p. 255)*. However, the goal of this activity is that students observe phenomena, discuss initial ideas, and ask questions. There are no specific content ideas that students should develop in this activity.	*Cause and effect:* Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. (NGSS Appendix G p. 83)	*Asking questions and defining problems:* Ask questions • that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. • that arise from examining models or a theory, to clarify and/or seek additional information and relationships. (NGSS Appendix F p. 51)

PREPARATION

Class Time: 45 min.

Materials

- Van de Graaff generator
- Bunsen burner
- a thick insulated surface to stand on (wood box or stable upside-down plastic crate)

Activity Setup

- Create a Unit 2 Driving Question Board with the question *How can a small spark start a huge explosion?*
- If you plan on doing the demo, set up the Bunsen burner and Van de Graaff generator near each other.

SAFETY ISSUES

- This activity includes several demos in which the Van de Graaff generator is used, including one with the Van de Graaff generator and a Bunsen burner. If you are uncomfortable performing these demos, you can use the videos provided instead. Carefully read the following safety tips.
- ***DO NOT* let students with electrical medical equipment near the Van de Graaff generator.** In particular, a Van de Graaff generator may be harmful to people with pacemakers or those dependent on other electrical medical equipment (cochlear implants, etc.). A Van de Graaff generator will only be hazardous if correct procedures are not followed. *DO NOT* let students use it unsupervised. See additional safety issues in the Appendix.
- This investigation includes a demonstration in which the teacher touches the Van de Graaff generator. If you choose to perform this demo, rather than showing the video, make sure you discharge the VDG ***before*** touching it.
- Be sure to have fire equipment (fire blanket, fire extinguisher, and emergency gas shutoff) on hand when lighting the Bunsen burner.

Activity 1.1 - Teacher Preparation

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Introducing the lesson

2. Prediction

    a. Demonstration

    b. Discussion

3. Energy and the Van de Graaff generator

    a. Driving question board

    b. Concluding the lesson

Activity 1.1 (Student materials): Can my finger start a fire?

DQ

Introducing the Lesson
Review the homework: Worksheet from Activity 5.4 (Unit 1).
Possible questions:

- *What solutions did you think of to keep hair from sticking up after you brush it?*
- *Any other ideas?*

Lead a class discussion to motivate the need for exploring energy. Revisit the demonstration of sparks coming from the Van de Graaff generator from Unit 1, Inv. 1 by either performing the demo again or showing this video. (See the Appendix for a review of how the Van de Graaff generator works.) Review the main ideas from Unit 1 (see questions below), and be sure to discuss ideas about how charged materials interact and how materials become charged.

We have a model of charge, but this model does not explain our observations of sparks. We cannot explain why we observe sound and light when a spark occurs, and we cannot explain why a spark can start a fire. Lead a class discussion to introduce the driving question for Unit 2 "How can a small spark start a huge explosion?" and raise additional questions.

Possible questions:

- *What questions do you have about why the sparks formed?*
- *What do we know about the Van de Graaff generator?*
- *What are some of the key ideas we added to our model in the last unit?*
- *Can these ideas help us explain sparks?*

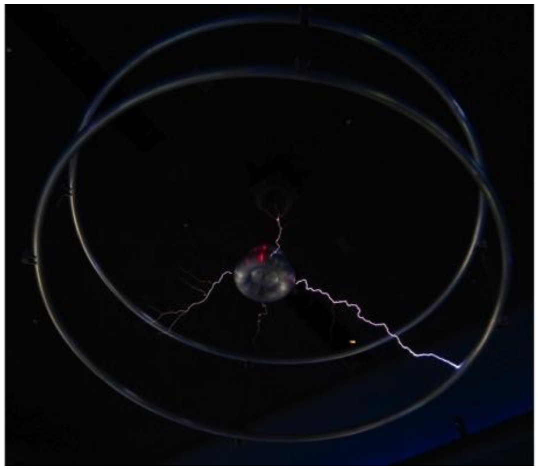
Be sure students bring up their understanding of atoms and charges.

Remember, as discussed in Unit 1 and the Appendix, it is important to elicit a variety of ideas from students during discussion. As students share their thinking, avoid evaluating their responses and try to respond neutrally to all ideas. Ask follow-up questions to get students to elaborate and share additional thoughts.

Possible questions:

- *How are your ideas similar and different?*
- *Which ideas best account for what we observed and what we know?*
- *Who can add more to the discussion?*
- *Who has a different way of thinking about these ideas?*
- *What evidence do you have to support your ideas?*

Page title:
Prediction



A Tesla coil creates giant sparks at the Museum of Science and Industry, Chicago, IL
Credit: Interactions Project (sys)

1. [prediction question] Can electric charge start a fire? Explain your thinking.

Student responses: The goal of this question is to elicit students' initial ideas and predictions. It is good to review and discuss these answers, but do not evaluate them. Push students to explain their thinking.

[prediction reveal with safety note below]

Safety Warning

DO NOT *attempt to do the demo shown in the video because there are significant hazards involved.*

Watch your teacher perform this demonstration: [Lighting a Bunsen burner with spark from finger](#).

Tip: After students answer Question 1, perform the following demonstration, or show [the video](#). This demo involves igniting a Bunsen burner using a spark from your finger. It grabs students' attention, but it is also hazardous. If you are unsure of your comfort level with the demo, show the video rather than doing the demo.

Here is some important safety information regarding the demo:

- This demo requires two people (a student can assist by turning on and off the gas and VDG, as described below). Make sure both people are following appropriate fire safety guidelines (long hair is tied up, no

Discussion
After students watch the demo, lead a brief discussion to help them generate questions that need to be answered in order to revise their current model in light of the new observations.

Possible questions:

- *Does our current model of charges explain how a spark can start a fire?*
- *Since we cannot see or hear charges, why can we see and hear sparks?*

NOTE: The goal here is to get students to realize that they cannot explain sparks or fire with their current model of charges. Thus, an answer of "I don't know" is appropriate here. After students have realized that their model of charges is missing some important aspects, develop questions that need to be answered to fill in the missing details. Record students' questions on the driving question board.

Ask students what questions they have regarding what caused the spark. Below are some possible questions to guide this discussion.
Possible questions:

- *In a previous investigation, we saw that paper near the Van de Graaff generator was affected by the electric field, but the paper did not burn. What is different here?*
- *What is it about a spark that might start a fire?*
- *What questions would we have to answer in order to develop a model that explains what a spark is and how it can start a fire? (Record students' questions on the driving question board.)*
    - *What could we add to our model to explain our observations of sparks?*
    - The goal of this part of the discussion is to raise the idea that the concept of energy is needed. If students raise energy as a missing point, great. Otherwise, students may identify observations that are missing: for example, the spark, or electricity. Follow up with questions to move the discussion to energy. For example, you could ask, *What do we observe when a spark occurs?* If students identify light and sound, you could point out that light and sound are both indicators of energy.

Add a new section to the driving question board that will be used to brainstorm ideas about energy, with the question, *What is energy?*

Once students have recognized that energy needs to be added to the model of charge, they will need to explore what energy is and define it. That is what students will do in the first few investigations of this unit.

Page title:
Questions about sparks and fire

In previous investigations, you developed a model of charge to explain your observations of interactions between objects. The Van de Graaff generator builds up a strong electric field, but this does not explain all of your observations. In the upcoming activities, you will develop a model of energy to explain observations that are not accounted for by your model of charge.

Energy is a common idea, but it is hard to define. Start by thinking about what you already know about energy.

2. Brainstorm about energy. What types of energy have you heard of?

Student responses: The goal of this question is to get students prepared for a class discussion about energy. Students should record a range of ideas. If students are stuck, push them to think of situations that are related to energy and the different ways energy is manifested in those situations.

3. What questions do you have about energy?

Student responses: Students may record questions that come up in the discussion, questions left from previous years, or questions about the phenomena being discussed in this curriculum. If students have a difficult time thinking of questions, coach them to think of questions that would help them answer the driving question for the unit.

Driving Question Board

Have the class brainstorm ideas about energy and their experience of energy in various situations.

Possible questions:

- *What does energy mean to you?*
- *Often, energy is discussed in terms of different types of energy. What types of energy have you heard of?*

Record ideas about what energy is and different types of energy on the driving question board under the question, *What is energy?* As students brainstorm, make sure the following ideas end up as part of the list. You can ask students guiding questions to elicit these ideas (for example, suggesting a scenario and asking students about the type of energy involved). Or you can simply add these ideas to the list—making your own suggestions as part of the brainstorming session.

- heat
- motion
- light
- sound

Page title:
Energy and the Van de Graaff generator

4. What types of energy do you think may have been involved when the Bunsen burner was lit with the spark from the Van de Graaff generator?

Student responses: Students should use the list from class notes and their observations to speculate about types of energy that may be included in the demonstration. There is no specific, expected answer to this question, but students may include:

- Light, sound, heat, fire

5. [drawing prompt] Draw an initial model to explain how the spark from the Van de Graaff generator lit the Bunsen burner.

[text prompt] Describe your model.

Student responses: Because students have not yet studied energy or developed a model that could explain the spark or flame, students' models may just show what they observed. Push students to think about what they already know about how the Van de Graaff generator works. You can also encourage students to remember what they have learned about creating models (model should provide a causal mechanism and may include invisible components).

6. What questions do you have about why the spark could start the fire?

Student responses: Students may record questions that were raised earlier in the class discussions. If students are stuck, ask them to think about what they need to know in order to add more to their model or to answer the driving question. There is no expected response here, but questions could include:

- What kind of energy is in the spark or fire?
- Where does the energy come from?
- What makes the spark or fire?

Concluding the Lesson
Wrap up the introduction.

Possible questions:

- *What types of energy do you think were involved in the demo with the Van de Graaff and Bunsen burner?*
- *Be sure to ask students to cite evidence: What did you observe that makes you think that type of energy might have been present?*
- *Ask other students what they think: Does anyone agree? Does anyone think a different type of energy might have been present?*

You may wish to have students display their initial models from the question about sparks from the VDG above, and discuss similarities and differences.

Introduce the driving question for the unit: *How can a small spark start a huge explosion?*

Record students' initial ideas and questions on the driving question board.

Note: Do not have students try to answer the questions at this point; just record their initial ideas and discuss which might be related, as well as which need to be explored further in order to answer the driving question for the unit.

Activity 1.2: What happens to energy when objects collide?

SUMMARY

Students will explore simple systems involving the transfer of kinetic energy. The idea of conservation of energy will be introduced/discovered through a computer simulation. Students will track energy through their observations of collisions. Certain processes (e.g, why a ball stops bouncing) will lead to the question of where energy goes and the need for the idea of potential energy, which will be addressed in next activity. Students will investigate the relationship between speed and changes in kinetic energy as a result of energy transfer.

LEARNING GOALS

- Students will develop a model of energy that allows them to track the transfer of energy.
- Students will develop model of energy that includes conservation of energy.
- Students will identify necessary components to define a system and its surroundings.

Disciplinary core idea	Crosscutting concept	Science and engineering practice
Definitions of energy: At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (NGSS Lead States, p. 255)	*Systems and system models:* Students investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. (NGSS Appendix G p. 85)	*Developing and using models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. (NGSS Appendix F p. 53)

POINT FOR CONSIDERATION

Students sometimes directly link the speed and kinetic energy of an object without considering its mass. In this activity, students will look at kinetic energy qualitatively, without using the formula for kinetic energy. As long as mass is constant, speed can be used as an indicator of kinetic energy, but it should be emphasized that this only works when mass is held constant.

PREPARATION

Class Time: 180 min.

Materials

- flour
- clay
- marble or small metal ball or small styrofoam ball

(for each group)

- two balls that are the same size and mass. (For example: two billiard balls, two steel balls, two tennis balls, two golf balls; balls made of softer materials, such as foam or "nerf" balls, will not work well.)
- Each group needs a third ball that is a different mass. (Pass out the third ball later.)
- basketball
- tennis ball

Activity Setup

- Make two clay balls that are the same size but have different masses. One way to do this would be to make one ball by coating the marble or steel ball with clay, and making a second one using only solid clay or by coating the small styrofoam ball with clay.
- Make at least one more ball with the same mass as either the heavy or light ball, so you will end up with one heavy and two light balls or one light and two heavy balls.

HOMEWORK

Reading for Activity 1.2: Energy as an Accounting System

Activity 1.2 - Teacher Preparation

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Introducing the lesson
2. Energy and motion
    a. Factors that affect kinetic energy demonstration
    b. Discussion of demonstration
    c. Scientific explanations
    d. Discussion
3. Changes in motion and energy
    a. Experiment
    b. Discussion - introducing energy bar graphs
    c. Discussion of energy graphs
4. Collisions with different masses
    a. Experiment
    b. Discussion
5. Motion and energy simulation
    a. Simulation
    b. Discussion
6. Conclusion
    a. Demonstration
    b. Revisiting the driving question

Activity 1.2: What happens to energy when objects collide?

Introducing the Lesson

Pull up the brainstorm list of types of energy. Remind students that we are thinking about how sparks can start fires. In order to understand this phenomenon, we need to understand energy. Explain that energy is a difficult concept to define, but it is related to changes in motion and position of objects within a system.

Students will start by looking at kinetic energy because it is easiest to observe. If kinetic energy or energy of motion is included on the brainstorm list, refer students to that type of energy. If kinetic energy is not included, add it to the list. Be sure to define kinetic energy—the energy associated with moving objects. Engage in a brief discussion about factors that might affect kinetic energy/energy of motion. Elicit students' ideas and raise questions, but do not answer those questions at this point.

Possible questions:

- *What does* kinetic energy *mean?*
- *How could you tell if an object has kinetic energy/energy of motion or if kinetic energy/energy of motion is involved in a scenario?*
- *What factors do you think might affect kinetic energy/energy of motion?*

Introduce the driving question for this activity: *What happens to energy when objects collide?*

Page title:
Energy and motion

1. What factors might affect the amount of kinetic energy an object has?

Student responses: This question is to elicit students initial ideas. Students may have studied energy and recall some information, or students may be making predictions. It is not expected that students agree on factors that affect the amount of kinetic energy at this point.

Demonstration

Perform the following demonstration to prompt discussion of factors that affect kinetic energy.

- Set four equivalent piles of flour spaced apart from each other.
- Make two pairs of clay spheres. The spheres in the first pair should have different masses. The spheres in the second pair should have the same mass. All four spheres should be the same size. Refer to the video below for more details.
- Record the mass of each clay ball. Tell students how you made the balls so that they have different masses (wrapping clay around a small styrofoam ball).
- Take two balls of different masses and perform the following demo. Hold a ball in each hand above two separate piles of flour. Instruct students to pay attention to each ball's speed as it drops and any changes they observe in the piles flour as the balls land. Drop both balls at the same time from the same height. Ask students to discuss their observations.

You can watch the following video to help you prepare to conduct the demo successfully in your classroom: Factors that affect kinetic energy demo.

Possible questions:

- *Is energy involved when a ball is dropped on a pile of flour? (Be sure to ask students to support their claims with evidence.)*
- *What changes do you observe? Do you observe any other changes? NOTE: There are a lot of changes; be sure to probe students for a variety of observations.*
- *How were the lighter clay ball and the heavier clay ball different?*
- *How did that affect the outcome?*
- *Which ball had more kinetic energy as it fell? What is your evidence?*

Take two balls of the same mass and perform the following demo. Throw one of the balls from about the same height that you threw the previous pair, but use more force so that it has a harder impact than the balls in the previous demo did when they were dropped from the same height. Drop the other ball from the same height with no force (like in the first demo). Ask students to discuss their observations.

Possible questions:

- *What was different about the clay balls in the two scenarios?*
- *How did that affect the outcome?*
- *Which balls had more energy? What is your evidence?*

2. Write a complete scientific explanation to account for why the heavier ball caused more flour to spread out. Be sure to include the relationship between amount of mass and amount of kinetic energy in your explanation, and include a claim, evidence, and reasoning.

Supplemental content: In this case, we made one ball lighter by decreasing the density when we added the styrofoam ball, which includes spaces filled with air. This left the other ball with significantly more particles in the same space, giving it a higher density and mass. One should not in general equate the size or number of particles with mass, because each particle can have a different mass. However, in this case the space between particles in the air in the styrofoam outweighs any differences in particle mass, so we can safely assume there are fewer particles in the ball partially made of styrofoam.

Clarification - You may want to discuss this point with students, but it is not a focus of the question or necessary for students to include in their answer. You could encourage students to make sure their answer is specific to this case and that they did not generalize the relationship between mass and number of particles.

Student responses: Students should indicate that as the mass of the ball increases, the amount of kinetic energy that is associated with that ball also increases (or vice versa). To support their answer, students should refer to evidence from the balls of different masses being dropped on the piles of flour and their observations of how far the flour moved. For the reasoning, students should draw on ideas that have been agreed upon as a class. For example, the students might pull in the idea of density from previous science classes, or they could try to use ideas from the particle nature of matter that was developed in Unit 1.

- The more mass an object has, the more kinetic energy it has when it is moving at a given speed. Dropping the balls on the piles of flour supported this idea because the pile under the heavier ball had a larger crater. In this case, the lighter ball had less atoms and the heavier ball had more atoms. Moving more atoms requires more force and so the heavier object has more energy associated with it.
- More mass means more kinetic energy.
    - *Ask student to support their answer with their observations and understanding of mass and kinetic energy.*
- Mass affects kinetic energy.
    - *Ask student to explain how mass and kinetic energy are related?*
- The heavier ball made a bigger impact on the flour.
    - *Push student to connect this observation to a claim.*

3. Write a complete scientific explanation to account for why the ball that was moving faster caused more flour to spread out.

Student responses: Students should indicate that as the speed of the ball increases, the amount of kinetic energy associated with the ball also increases (or vice versa). To support their answer, students should refer to their observations of balls with the same mass being dropped versus thrown, and how far the flour moved.

- Objects with a higher speed have more kinetic energy. The ball that was thrown made a larger crater. Kinetic energy is energy associated with motion. The faster an object moves, the more kinetic energy it has.
- How fast an object moves changes how much kinetic energy it has.
    - *Ask student to specify the relationship between speed and kinetic energy.*
- The one that was thrown made a larger crater in the flour.
    - *Ask student to generalize this observation and support with their understanding of kinetic energy.*

Discussion

Have students share their explanations about why the heavier and the faster ball caused more flour to spread out. Ask them to describe what is similar and different about the various explanations. If students have different explanations, this provides a good opportunity to have them argue their points using evidence. By the end of the discussion, make sure students have come to a consensus about the relationship between speed and kinetic energy, and the relationship between mass and kinetic energy to explain the observed phenomena.

Possible questions:

- *Does anyone agree/disagree with that explanation?*
- *Does anyone think we need to add something else?*

Page title:
Changes in motion and energy

Materials
- 2 spheres with the same size and mass

Try rolling the spheres toward each other. Note what happens to the speed and direction of each sphere when they collide. Test at least four different methods of having the spheres collide, which may include the following:
- Set one sphere in place, and roll the other sphere toward it.
- Roll both spheres toward each other with the same initial speed.
- Roll both spheres toward each other with different initial speeds.

For every test you run, record your observations about the motion of each object before and after the collision.

Observations of motion before collision	Observations of motion after collision

Please note: *Any time an interactive table is included, a question number in the activity will be skipped and so the report numbering will not match the activity numbering.*
http://lab.concord.org/embeddable.html#interactives/interactions/collision-table-U2-Inv1.json

4.Take a snapshot of your data table.

Supplemental content: While energy is conserved, the speed of the balls during the collision is not necessarily conserved. If the objects do not hit directly head-on, they may roll off at odd angles with different speeds. Also, make sure the experiment is done on a level surface so that the changes in speed are due to the collisions, not gravity.

Clarification - students should be recording their observations, not explaining or evaluating them.

Student responses: Students should record their observations; observations will vary depending on the initial setup.
- One ball hit a stationary one, the first one stopped and the other one rolled away with about the same speed.
- When both balls were rolled toward each other, they both bounced back at about the same speed.
- They bounced back
  - *Push students to try to be specific, and note additional details about the direction and speed.*

Discussion

Discuss students' observations of the collisions, and define an accounting system for keeping track of the energy. Students will need to be shown examples to help them develop the use of graphs to track the energy of a system. Focus students' attention on the following question: *How can we explain the movement of the spheres (the phenomenon) by keeping track of the energies involved?*

Make sure the discussion includes these two important points:

1. One way to think of energy is as an accounting system for keeping track of what happens during changes.
2. How the system is defined (which objects you include in your system) will affect how the accounting is done.

Begin the discussion by reviewing the data tables and identifying patterns in observations. Provide an accounting model of energy, such as the following: "Energy is a very useful idea in science for keeping track of what happens during changes. Energy can be thought of as an accounting system that allows you to identify what is going in and what is coming out during a change. In this accounting system, graphs can be used as a way to keep track of the changes." (See the Appendix for more information on energy graphs.) Then discuss the importance of defining the system—deciding which objects to include. Anything that is not included is considered part of the surroundings. As examples, make some energy graphs as a class. See the *Framework for K–12 Science Education* for more information on systems.

Below is an example outline of how you might structure this discussion:

1. Review a simple case, such as a collision of two objects with the same mass in which one starts out stationary.
    - Ask if any groups tested a collision of two similar objects by placing one on the table and rolling the other one toward it.
        - *What did you observe after the collision?*
        - *Did other groups see something similar or different with the same type of test?*
        - Ideally in this case, students should identify that the ball that was rolled stopped or slowed down significantly after the collision, and the ball that was stationary rolled away. If students do not provide all these components, ask clarifying questions.
    - Ask students to define the system.
        - *One way to think of energy is as an accounting system for keeping track of what happens during changes. If we want to keep track of what happened in this situation, what would we need to include?*
        - *Why would that be an important component to include?*
        - Ask students to come to a consensus about what should be included.
        - Inform students that this is called *defining the system*. The system identifies the objects you are considering while tracking changes.
        - Anything that is not included in the system is considered part of the surroundings.
    - As a class, develop an example of how the energy can be tracked during the change. For instance, you could use bar graphs (see Appendix).
        - *In the beginning, what was the relative motion of each ball?*
        - *If we use speed as an indicator of kinetic energy, how does the kinetic energy of the two objects compare?*

      Important note: We can use speed as an indicator of kinetic energy in this case ONLY because the two colliding objects are very similar (same mass, material, etc.).
        - *How does the kinetic energy of the two objects compare after the collision? Ask students to compare the speed of the moving ball after the collision with the speed of the moving ball before the collision. Use this comparison to decide how tall to make the bars.*
2. Review a case in which both balls are moving before they collide.
    - Ask a group to share their observations of a test they did in which both objects started out moving.
    - Discuss how to define the system. Come to a consensus about which objects to include in the system.
    - Discuss the relative speed of each object before and after the

5. [drawing prompt] Make an energy graph for a collision method that you tested but have not yet discussed with the class. When making your graph, be sure to decide the following:

- **What to include in the system**
- **The relative kinetic energy before and after the collision**
- **How to represent the change**

Student responses: Answers will vary. The graph should display the relative energy of each object before and after the collision. NOTE: Students' assumptions about the amount of energy may not be accurate at this point. For example, at this point, it is okay if the total energy is not clearly conserved in their graph.

Discussion of Results

Have groups display the graphs they created. Discuss the idea of energy transfer and whether or not they think the total amount of energy stayed the same.

Possible questions:

- *How is kinetic energy represented on your graph?*
- *What caused the objects' kinetic energy to change?*
- *For the objects that were initially stationary, what had to happen to them in order for them to start moving?*
- *What might have happened during the collision that caused the stationary object to start moving?*
- *Which models do a good job of explaining the observations of the spheres?*
- *Who has a different way of thinking about these ideas?*

Use students' responses to introduce the term *transfer of energy*.

Tip: By the end of this discussion, students should be able to describe the following ideas:

- System - all the objects that are included in an analysis of energy changes
- Surroundings - objects that are not included in the system but may still interact with it
- Energy transfer - movement of energy from one object to another

Students should also realize that depending on how they define the system, their graphs of the same situation may look different. This is fine. But no matter how they define the system, their graph must account for all energy changes.

Page title:
Collisions with different masses

Get a new sphere that has a different mass from the two you used earlier.

Collide the new sphere with one of the spheres you used earlier. Again, try at least four different methods of collision, which may include the following:

- Set the lighter sphere in place, and roll the heavier sphere toward it.
- Set the heavier sphere in place, and roll the lighter sphere toward it.
- Roll both spheres toward each other with the same initial speed.

For every test you run, record your observations about the motion of each object before and after the collision.

Observations of motion before collision	Observations of motion after collision

Please note: *Any time an interactive table is included, a question number in the activity will be skipped and so the report numbering will not match the activity numbering.*
http://lab.concord.org/interactives.html#interactives/interactions/collision-table-U2-Inv1.json

7. Take a snapshot of your data table.

Supplemental content: While energy is conserved, the speed of the balls during the collision is not necessarily conserved. If the objects do not hit directly head-on, they may roll off at odd angles with different speeds. For example, if a heavier ball hits a lighter ball, the lighter ball will move faster, but since mass and speed both impact the amount of kinetic energy the lighter faster ball has the (approximately) same kinetic energy that was lost by the heavier ball. Also, make sure the experiment is done on a level surface so that the changes in speed are due to the collisions, not gravity.

Clarification - students should be recording their observations, not explaining or evaluating them.

Student responses: Students should record their observations; observations will vary depending on the initial set-up.

- One ball hit a stationary one, the first one stopped and the other one rolled away with about the same speed.
- When both balls were rolled toward each other, the both bounced back at about the same speed.
- They bounced back
  - *Push students to try to be specific and note additional details about the direction and speed.*

Discussion
Display the data tables and discuss the results.

Possible questions:
- *Does anyone notice any patterns?*
- *Are their any combinations that were not tested? What do you think would happen in that scenario?*
- *Did different groups get similar results with similar tests?*

8. Compare your observations of the collisions of spheres that had different masses with your earlier observations of the collisions of spheres that had the same mass.

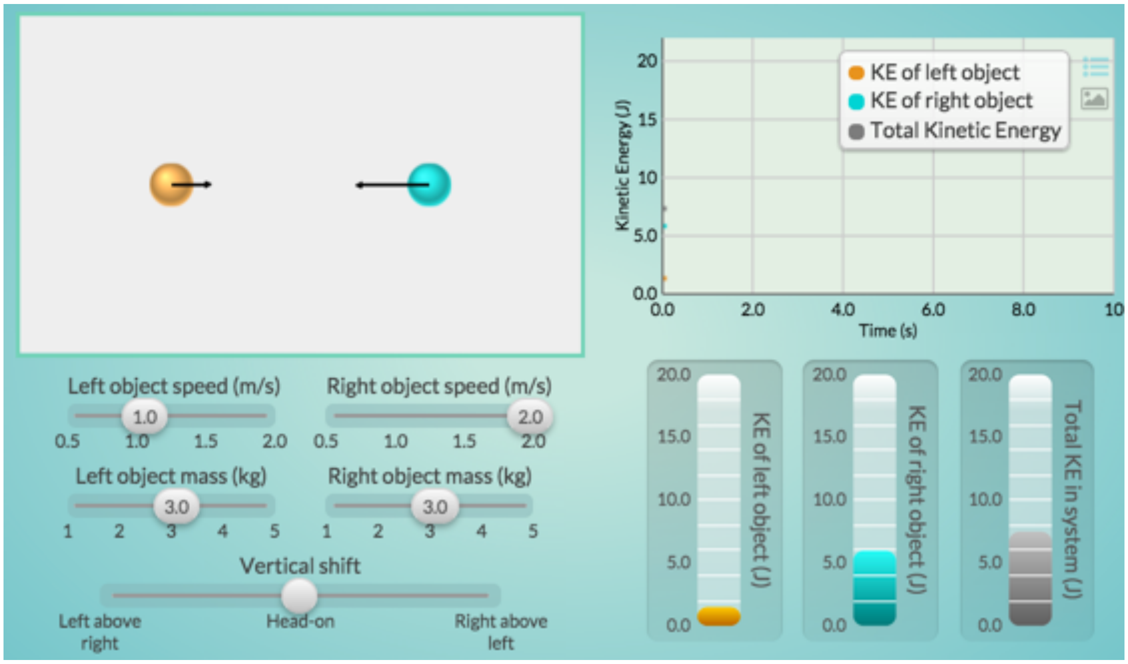
Student responses: Students are still working on their initial ideas here, so students may note different aspects of these tests. Students could include ideas similar to:
- The lighter ball changed speed more.
- All the collisions made the speed or direction of the balls change.

9. Based on your observations so far, do you think the total amount of energy changes when two spheres collide? Justify your answer.

Student responses: Answers will vary. At this point, students do not have enough evidence for conservation of energy, so it is fine if they disagree or think that kinetic energy is not conserved.
- Yes, because the spheres had different speeds after colliding.
- Can't tell because even though the spheres had different speeds, they also had different masses and both mass and speed affect how much energy an object has.
- No, because energy is conserved.
    - *Push student to connect this idea with the observations with the colliding spheres.*

Page title:
Motion and energy simulation

Use the simulation to explore why heavier and lighter spheres move at different speeds after a collision. Be sure to test a variety of combinations of mass and speed.



Simulation link: http://lab.concord.org/interactives.html#interactives/interactions/collision.json

11. [snapshot prompt] Take a snapshot of the simulation and add annotations to show *the relationship between the mass and kinetic energy* of an object.
[text prompt] Use your image to describe the relationship between the mass and the kinetic energy of an object.

Sample responses: Students can take a snapshot of two balls that have different masses but the same speed, and the graphs will show that the ball with greater mass has higher kinetic energy. Students should point out the connections between the speed and mass shown by the slider settings, and the energy shown on the bar graphs.

12. [snapshot prompt] Take a snapshot of the simulation and add annotations to show *the relationship between the speed and kinetic energy* of an object.
[text prompt] Use your image to describe the relationship between speed and kinetic energy of an object.

Student responses: Students can take a snapshot of two balls that have different speeds but the same mass, and the graphs will show that the ball with higher speed has higher kinetic energy. They can also use two balls with the same speed but different masses to show the relationship between mass and kinetic energy. Students should point out the connections between the speed and mass shown by the slider settings, and the energy shown on the bar graphs.

13. What pattern do you notice about the total amount of kinetic energy before and after each collision in the simulation? Justify your answer using evidence from the simulation.

Student responses: Students should note that the total kinetic energy is always the same before and after a collision. Students should refer to at least one run of the simulation to support their claim; however, referring to multiple runs is stronger evidence.

- The total energy never changes. When a light and heavy ball collide, the lighter ball moves faster but the energy still adds up to the energy lost by the heavy ball. Similarly, when a fast and slow ball collide, the slow ball speeds up but the fast ball loses the same amount of energy.
- The energy does not change.
    - *Ask students to refer to some of the trials they completed in the simulation to support this.*
- The energy goes up and down.
    - *Make sure students are analyzing the total energy in addition to the energy of the different objects.*

Discussion

Review the model shown in the simulation by asking students to identify the components, relationships, and connection to phenomena.

- What are the components/variables of the model shown in the simulation? (both visible and invisible)
- What are the relationships between those variables?
- How does the model help explain what happened when the marbles collided?

Ask students to share the conclusions they developed by exploring the simulation.

Possible questions:

- *What did you notice about the energy during collisions?*
- *What has to be true in order for an object to lose or gain kinetic energy?*

Be sure to ask students to elaborate on their answers.

Define *conservation of energy*. Explain that the total amount of energy must remain constant during any change. That is why, when keeping an account of energy changes, it is important to track all of the energy in the system.

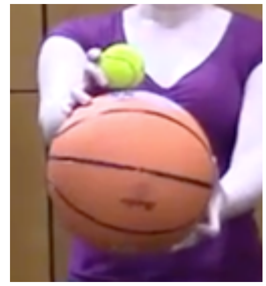
Revisit the energy graphs students drew of the hands-on activity involving ball collisions.

- *How does the idea of conservation of energy apply to the hands-on tests as well?*
- *Should the total energy (system and surroundings) remain constant in the hands-on tests as well? (Be sure to ask students to explain their answer.)*
- *How does the simulation compare with our observations of the two balls rolling toward each other?*

Students may wish to revise their original graphs to more accurately represent conservation of energy.

Page title:
Conclusion

Observe the demonstration of bouncing balls conducted by your teacher, and answer the following question.



Concluding the Lesson
End the lesson with a demo and formative assessment.

Demo

- Drop a basketball on the floor and have students observe how high it bounces.
- Then drop a tennis ball from the same height and have students watch how high it bounces.
- Finally, place the tennis ball directly on top of the basketball. Tell students that you are going to drop the balls together. Ask them to predict what will happen when you drop the balls. Drop the tennis ball and basketball together. (If the demo is successful, the tennis ball will fly off *to a much higher point* than the basketball, and the basketball will barely bounce. You can watch the following video to help you prepare to conduct the demo successfully in your classroom: Basketball and tennis ball demo.). Perform the demo twice and ask the students to first observe the tennis ball and then the basketball. Now ask students to describe what they observed. NOTE: It is likely that they won't notice that the basketball doesn't bounce as high, so you will probably need to do this a second time and focus students' attention on the basketball.

14. When the tennis ball and basketball are bounced together, why does the tennis ball bounce so high and the basketball bounce so low? Be sure to include the ideas of energy transfer and energy conservation that you developed in this activity.

Sample responses: To explain their observations, students should discuss energy transfer as well as the relative masses of the tennis ball and basketball.

- When the tennis ball and basketball are bounced together, some of the energy from the basketball is transferred to the tennis ball. The tennis ball is a lot lighter than the basketball, so the kinetic energy that gets transferred to the tennis ball makes it move a lot higher and faster than the basketball.

Revisiting the Driving Question

Revisit the driving question for the unit, *How can a small spark start a huge explosion?* Although this activity does not directly relate to the driving question, the activity does help build an understanding of energy, which is needed to answer the driving question.

Possible questions

- *How does observing collisions and bouncing balls help us explain sparks and explosions?*
  NOTE: Some students may not see a connection at this point, and that is fine. Others may recall that earlier the class established a need to understand energy before explaining sparks. Students do not need to give a detailed explanation at this point; the goal here is just to draw students back to the reason for developing an understanding of energy.

Revisit the DQ board with the question, *What is energy?* Add students' ideas and additional questions about energy.

Possible questions:

- *What ideas about energy should we add to our board?*
  NOTE: Only include ideas that the class agrees on. If there are some ideas that students have not come to a consensus about, do not yet include those ideas.
- *In order to use energy to answer our driving question about sparks and explosions, what other questions do we still need to answer?*

Homework: Reading for Activity 1.2
Energy as an Accounting System

Activity 1.3: If moving objects have kinetic energy, do moving atoms have kinetic energy?

SUMMARY

The purpose of this activity is to help students connect kinetic energy and thermal energy. In the previous activity, students learned about kinetic energy by observing collisions at the macroscopic level. In this activity, they will look at evidence to apply these ideas about kinetic energy at the atomic level. They will investigate connections between changes in the speed of particle motion with changes in the temperature of a system. In the next activity, students will continue to develop their model of energy by adding the idea of potential energy.

LEARNING GOAL

Students will further develop their atomic model by relating thermal energy to kinetic energy.

Disciplinary core idea	Crosscutting concept	Science and engineering practice
Definitions of energy: These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of particles). (NGSS Lead States, p. 256)	*Energy and Matter:* They [students] can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. (NGSS Appendix G p. 86)	*Developing and Using Models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system (NGSS Appendix F p. 53)

PREPARATION

Class Time: 45 min.

Materials

- 6–9 large beakers (500 mL or 1 L)
- hot plates (one for each large beaker)
- protective gloves (heat resistant)
- ice, freezer, or cold refrigerator
- water

(for each group)

- 3 small petri dishes
- 3 stopwatches
- thermometer
- food coloring
- eye dropper

Activity Setup

A. Print off copies of the lab sheet.
B. Fill 2 or 3 large beakers with water, and leave them out for several hours before class starts so that the water can come to room temperature.
C. Fill 2 or 3 large beakers with warm water, and place them on hot plates. Turn the hot plates to low so that the water gets warm but does not boil.
D. Fill the remaining 2 or 3 large beakers with cold water. Do one of the following to make the water very cold, but do not allow the water to freeze:
    a. Place the beaker in a cold refrigerator for a few hours.
    b. Place the beaker in a freezer for about 20 minutes.
    c. Add some ice cubes to the water.
E. Students will need to be able to use a pipette or dropper with the food coloring, so you may need to cut the top off the food coloring container or transfer some food coloring to a different container.

HANDOUTS

Lab sheet for Activity 1.3: Food Coloring and Water

SAFETY ISSUES

The hot water, hot plates, and hot beakers can cause burns. The area around the hot plates should be clear. *DO NOT* let students crowd around the heating beakers of water. Heat resistant gloves should be worn while pouring the hot water into petri dishes.

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Review relationship between object motion and kinetic energy
    a. Discussion

    b. Experiment

    c. Discussion of results and particle model

1. Food coloring and water simulation
    a. Simulation

    b. Discussion

    c. Scientific explanation

2. Concluding the lesson and revisiting the driving question
    a. Introduce the term "thermal energy"

    b. Discuss the driving question

Activity 1.3 (Student materials): If moving objects have kinetic energy, do moving atoms have kinetic energy?

Introducing the Lesson

Review from the previous activity the relationship between motion of objects and kinetic energy. Review how kinetic energy changes as a result of energy transfer. Ask students what question they still have about this.

Possible question:

- *What factors affect the amount of kinetic energy an object has?*
- *What are some ways in which energy be transferred?*
- *How does kinetic energy change when two moving objects interact?*

Remind students that in the last unit, they analyzed evidence that supports the idea that all matter is made of atoms. Ask them if atoms could have kinetic energy.

Possible questions:

- *Do you think atoms have kinetic energy?*
- *How could you tell if atoms have kinetic energy or not?*

In this activity, students will watch food coloring spread through water as a means of observing the motion of water molecules.

Page Title:
Food coloring and water

In this activity, you will make observations of the behavior of food coloring in water of different temperatures.

After completing the experiment described in the handout linked below, return to this activity to answer the following questions.

Experiment Instructions: Food coloring and water lab

1. In which temperature water did the food coloring spread the fastest?

A. The cold water
B. The room temperature water
C. The warm water
D. It was hard to see any difference.

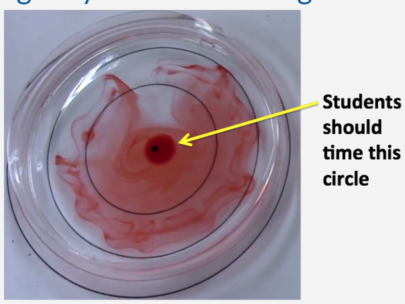
2. In which temperature water did the food coloring spread the slowest?

A. The cold water
B. The room temperature water
C. The warm water
D. It was hard to see any difference.

Tip: Depending on the setup in your classroom, you can have groups record the temperature of each sample of water on their own (if you have enough large beakers so that students can record this measurement without creating a bottleneck). Otherwise, you can measure the temperature of the three samples of water and have groups simply record the measurement you report.

The following video provides some tips for conducting this demonstration: [Tips for food coloring and water demo](#).

Make sure students are timing the dark circle of dye in the middle, not the light dye smears floating around.



You should deliver the warm water to the groups so that students are not carrying around petri dishes or other containers of warm water, which could cause burns.

There are a couple of tricks for getting the food coloring to spread correctly in the water:

- Students should not squeeze the food coloring into the water because the force of their squeeze will cause the mixing, and the goal is to have the mixing occur on its own.
- The drop needs to be placed below the surface of the water. Otherwise, surface tension will prevent the food coloring from mixing with the water.

The food coloring in the room temperature and cold water may take a while to reach the edge of the dish. Encourage students to move on in the investigation while they wait.

Discussion
Create a class data table to compare results of the lab.
Revisit ideas from the lab on the particle nature of matter in Unit 1 Investigation 5 (mixing ethanol and water).

Possible questions:
- *What did the water and ethanol or syringe experiments tell us about materials?*
- *What is the water and food coloring made of?*
- *What do you remember about how particles behave?*
- *Why did the volumes not add up in the water and ethanol lab?*
- *What is between the particles?*

Students should recall that all materials are made of particles and that there is empty space between particles.

Discuss the activity students just did focusing on ideas about why the dye spreads on its own.

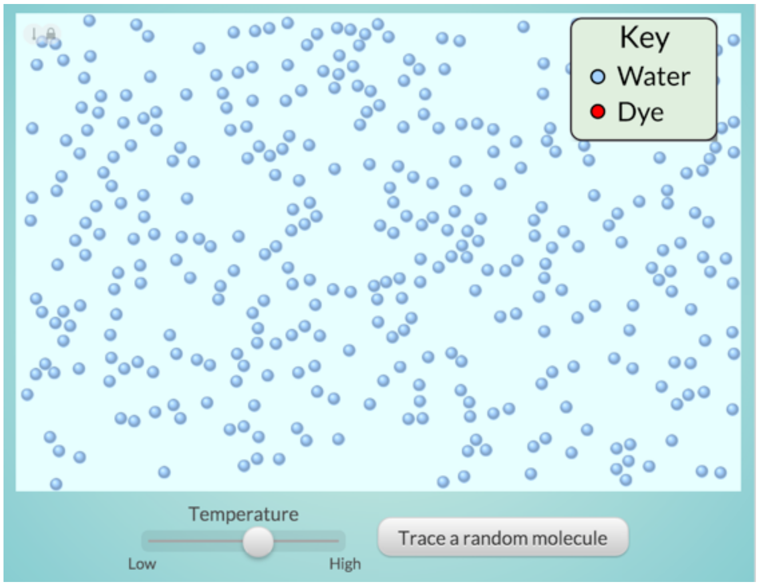
Possible questions:
- *Did we mix the dye or did it mix on its own? How?*
- *What does that tell us about the particles?*

3. What might explain why the dye spread at different speeds in the different temperatures of water?

Sample responses: At this point, students may not have a fully formed explanation, but they should try to connect the pattern they saw with ideas from the particle nature of matter.
- The water particles moved faster in the warmer water
- The dye particles moved faster in the warmer water
- The water particles pushed the dye particles around

Page title:
Simulating diffusion

Explore the simulation then answer the questions below.



Simulation link:
http://lab.concord.org/interactives.html#interactives/interactions/dropping-dye-with-temp.json

4. What did you notice about the behavior of particles in the simulation that helps dye mix with water?

Supplemental content: particles are in constant motion. By constantly colliding with each other they allow dye molecules to travel away from the place where the dye was originally dropped.

Clarification - students do not need to use the technical terms ("constant", "motion", "collision" etc.)

Sample responses: Students should have a general description of the patterns of particle behavior.

- Particles move in straight lines until they have a collision with another particle. The pattern that is observed as a result of these collisions is random
- Particles move across distance via collisions with other particles
- The dye particles are pushed around by bumping into the water particles

5. Write a complete scientific explanation about what causes the speed at which the dye spreads to differ in water of different temperatures. Use your observations as evidence and make sure to include the relationship between the temperature of the water and the motion of the molecules of water and dye.

Sample responses: Students should have a general description of the patterns of particle behavior. Students should make a claim about the relationship between the water temperature and the speed at which the food coloring spread. Students should support this claim with evidence from their data table. Students' reasoning should include atomic-level explanations.

- . The higher the temperature, the faster the spread of dye occurred. When the water temperature was ___, it took ___ for the food coloring to spread. But when the temperature was ___ , it took ___ for the food coloring to spread. Water is made of particles (students may call them atoms or molecules at this point). The particles of water are moving around and bump into the particles of food coloring. The particles in the warmer water are moving faster, so they bump into the food coloring particles more quickly and more often because the food coloring mixes with the water faster.

6 . Which system (cold water, room temperature water, warm water) has atoms with the highest average kinetic energy? Justify your answer.

Sample responses: Students should state that the warmest water has atoms with the highest average kinetic energy. To support their answer, students may use their observations and/or the relationship between the speed and kinetic energy of objects.

- When the water temperature was ___, it took ___ for the food coloring to spread. But when the temperature was ___ , it took ___ for the food coloring to spread. Therefore, molecules move faster at higher temperatures. Since objects with higher speed have more kinetic energy, it means that particles at higher temperatures have more kinetic energy

Concluding the Lesson
Discuss the patterns students saw and the conclusions they made.

Possible questions:

- *Do particles behave differently at different temperatures? If yes, how and why?*
- *Was there energy in each water system? Be sure to ask students to support their answers with evidence.*

Introduce thermal energy: "Since atoms are in motion, they have kinetic energy. However, the kinetic energy of atoms has a special name. It is called *thermal energy*."

Possible questions:

- *Which water system (cool, room temperature, or warm) has molecules with the highest average kinetic energy? What is your evidence?*

Discuss the idea that temperature gives us some information about the kinetic energy of molecules and thus their motion.

Revisiting the Driving Question
Students may need to be reminded of the reason for studying energy. Refer to the DQ board with the question, *What is energy?* Ask students about what they have learned and what still needs to be developed in order to answer the driving question for the unit: *How can a small spark start a huge explosion?*

Possible questions:

- *What have we learned about energy so far?*
- *How do these activities relate to our original driving question?*
- *What questions do we still need to answer in order to explain how a small spark can start a huge explosion?*

Activity 1.4: If energy cannot go away, why don't things move forever?

SUMMARY

This activity starts with a discussion to motivate the need for another form of energy—potential energy. In the next investigation, students will develop a deeper understanding of potential energy. But here, potential energy is only discussed as a form of energy that could be used and that is different from kinetic energy. Students will explore how kinetic and potential energy are related to energy conservation. Students will also describe energy as kinetic, potential, or evidence of an energy transfer. In the next investigation, students will describe how energy is stored and identify potential energy as a form of energy associated with an object's position in relation to other objects in the system.

LEARNING GOALS

- Students will develop a model of energy that includes energy conversion, energy transfer, and conservation of energy.
- Students will analyze data to track energy throughout a process using the ideas of energy transfer and energy conversion between kinetic and potential energy.

Disciplinary core idea	Crosscutting concept	Science and engineering practice
Conservation of Energy and Energy Transfer • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (NGSS Lead States, p. 98)	*Energy and Matter:* They [students] can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. (NGSS Appendix G p. 86)	*Constructing explanations and designing solutions:* Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (NGSS Appendix F p. 61)

POINTS FOR CONSIDERATION

- Students often think that different types or forms of energy are different things. When discussing kinetic and potential energy, it is important to emphasize that this is all the same energy—just in different forms.
- Light and sound are often discussed as forms of energy; however, the *Framework for K–12 Science Education* (National Research Council, 2013; available at http://www.nap.edu/catalog.php?record_id=13165#) suggests that it is more useful to think of light and sound as different manifestation of energy at the macroscopic level.

PREPARATION

Class Time: 45 min.

Materials

- basketball
- lump of clay (1 lb.)
- pendulum

HOMEWORK

Reading for Activity 1.4: Energy Conservation

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Pendulum demo
    a. Discussion
    b. Revisiting the driving question
2. Ball drop demo
    a. Demo
    b. Discussion
    c. Questions
    d. Discussion
3. Pendulum and energy
    a. Simulation
    b. Discussion
    c. Concluding the lesson

Activity 1.4 (Student materials): If energy cannot go away, why don't things move forever?

Introducing the Lesson

Start the lesson by presenting the following demonstration. Using a pendulum, show students that eventually a moving object (that has kinetic energy) will stop. In this demonstration, the goal is to get the pendulum to swing for a while, but then for the pendulum to slow down and stop.

Page title:
Pendulum demo

A giant pendulum keeps time at the Museum of Science and Industry Chicago, IL.
Credit: Interactions Project (sys)

Your teacher will perform a demonstration using a pendulum.

1. Observe the pendulum from when it starts until when it stops swinging. Identify any forms of energy you think are related to your observations.

Supplemental content: Before the pendulum is let go it has potential energy due to it's relative position towards the Earth. Once it is let go, potential energy is converted to kinetic (pendulum moves). Gradually all of the kinetic energy is converted to thermal energy (particles that make up the air, move faster as a result of colliding with with the pendulum.). The motion of the pendulum warms the air around it and through friction with the air the parts of the pendulum get warmer too.. Once all the energy has been converted, the pendulum stops moving.

Clarification - students are not expected to mention potential energy at this point, but some of them might.

Student responses: Students *should recognize that when the pendulum is moving it has kinetic energy and when it stops, the pendulum does not have kinetic energy*

- Pendulum has kinetic energy when it is moving
- Pendulum has potential energy before it is let go and this potential energy is converted to kinetic when it is let go
  - *Ask students to explain the difference between potential and kinetic energy*
- Pendulum has kinetic energy when it is moving and no energy when it stops
  - *Ask students to reason about where the energy of the pendulum comes from and where it goes when it stops*

Discussion
At this time, do not discuss the potential energy involved in the pendulum swinging. Just note that the kinetic energy eventually seems to end .

Repeat the demo, and discuss students' observations and ideas about energy.

Possible questions:

- *How can you describe energy changes related to your observations of the swinging pendulum? Support your answer with evidence.*
- *Is energy conserved in this demonstration? NOTE: Ask students to use their observations to support their answers. Students may disagree about whether or not the energy is conserved in this case, which is okay at this point.*
- *Recall that we stated that energy must be conserved. Does the pendulum have energy when it has stopped swinging? Support your answer by explaining what type or types of energy are present when the pendulum stops swinging.*
- *What might be some possible explanations for what happened to the kinetic energy of the pendulum?*

Tip: Students may bring up potential energy. If they do, ask them to define what they mean by *potential energy,* since that idea has not yet been developed by the class.

2. Describe any energy changes that occur as the pendulum swings and slows down.

Student responses: Students' answers will vary but students should be able to identify that kinetic energy of the pendulum varies.

- As the pendulum slows down, the kinetic energy decreases.
- When the pendulum swings energy is converted between potential and kinetic energy.

Revisiting the Driving Question
Project some students' answers as examples, and discuss conservation of energy.

Possible questions:

- *Do all of these examples show conservation of energy?*
- *If they show conservation of energy, where does the kinetic energy go?*

Revisit idea of surroundings.
Possible question:

- *Recall that everything that is not part of the system is part of the surroundings. What might be some important objects in the surroundings to consider in this example?*
- *Energy transfer also happens within the system. What are components of the system that gain or lose energy when the pendulum is swinging?*

Ask for other examples in which it seems like the kinetic energy is not conserved.
Possible questions:

- *What other examples can you think of in which it seems like kinetic energy is not conserved?*
- *Are there other examples in which energy is involved, but you can't see anything moving?*

Introduce the driving question for this activity: *If energy cannot go away, why don't things move forever?*

Page title:
Ball drop demo

Demo
Place a clump of clay on the ground. Hold a heavy ball, such as a basketball, over the clump of clay. Drop the ball so that it sticks to the clay when landing on it. You can watch the following video to help you prepare to conduct the demo successfully in your classroom: Ball and clay demo. When you conduct this demo, make sure students are able to see the difference between the shape of the clay before the ball was dropped to after. Depending on the clay you use, it may work better to use a smaller piece, or create a particular shape (for example, a pyramid) so students can easily see a difference.

3. Observe the ball that your teacher drops. Identify any forms of energy you think are related to your observations.

Supplemental content: Before the ball is let go it has potential energy due to it's relative position towards the Earth. Once it is dropped, potential energy is converted to kinetic (the ball moves). When the ball is dropped on clay, The kinetic energy is transferred to the molecules of clay. When the ball hits the clay, the molecules in the clay are moved around. Theoretically, with sensitive enough instruments, you could detect a small increase in the temperature of the clay and the ball due to the increase in the movement of the molecules. The same increase in temperature could be observed for the molecules of the air that are in contact with the moving ball, and molecules of the floor that are in contact with the clay.

Clarification - students are not expected to mention potential energy or connect the clay to movement of molecules (thermal energy) at this point, but some of them might.

Student responses: Students should recognize that when the ball is let go it has kinetic energy and when it stops, ball no longer has kinetic energy.

- The ball has kinetic energy when it bounces
- The ball has potential energy before it is let go and kinetic when it is let go
  - *Ask students to explain the difference between potential and kinetic energy*
- The ball has kinetic energy when it is moving and no kinetic energy when it stops
  - *Ask students to reason about where the energy of the ball comes from and where it goes when it stops*

Discussion
Repeat the demo and discuss energy.

Hold the ball above the clay, but do not drop it yet.

Possible questions:
- *When I am holding the ball in the air, does it have kinetic energy?*
- *If I let the ball go, will it have kinetic energy?*
- *If I drop the ball, where will the kinetic energy come from?*

Introduce idea of potential energy. Explain that this example demonstrates that kinetic energy is not always conserved. But for our accounting system, we have to be able to keep track of of energy and where it goes after a change. In order for our accounts to stay balanced, we need to describe another form of energy. NOTE: Do not define potential energy at this point; just explain that it is a form of energy that is different from kinetic energy.

Drop the ball on the clay.

Possible questions:
- *As the ball is falling, what energy does it have?*
- *After the ball hits the clay, what energy does it have?*
- *After the ball hits the clay, where could the energy have gone?*
- *What could be happening in the clay when the ball hits it?*

4. What do you think happens at the molecular level when the ball lands on the clay?

Supplemental content: Before the ball is let go it has potential energy due to it's relative position towards the Earth. Once it is let go, potential energy is converted to kinetic (the ball moves). When it lands on the clay, the kinetic energy of the ball is transferred to the molecules of the clay.

Clarification - Students are not expected to say that the ball transfers energy to the molecules of the clay. They are not expected to reach consensus at this point. This is a formative question.

Student responses: Students should recognize that when the ball is moving it has kinetic energy and when it stops the energy is transferred to the surroundings
- The ball transfers energy to the molecules of the clay
- The ball transfers energy to the surroundings
- The molecules in the clay got pushed around when the ball hit

5. How might your answer to the previous question help explain what happens to molecules that make up the ball and the clay when the ball lands on the clay?

Supplemental content: Before the ball is let go it has potential energy due to it's relative position towards the Earth. Once it is let go, potential energy is converted to kinetic (the ball moves). When it lands on the clay, the kinetic energy of the molecules of the ball is transferred to the molecules of the clay through collisions.

Clarification - Students are not expected to say that the molecules of the ball transfers energy to the molecules of the clay. They are not expected to reach consensus at this point. This is a formative question.

Student responses: Students should recognize that when the ball is moving it has kinetic energy and when it stops it no longer has kinetic energy

- The ball has kinetic energy when the ball is moving. When the ball hits the clay, the clay and the ball get smushed, which pushes the molecules closer together and transfers energy into movement of the ball and clay molecules.
- The molecules of the ball transfers energy to the molecules of the clay
    - *Ask students to explain the process*

6. How might your answers to the two previous questions help explain what happens to the pendulum's kinetic energy when the pendulum stops swinging?

Student responses: This is a formative question, students are not expect to reach a consensus at this point. However, students should be able to recognize similarities between the pendulum and basketball:both have potential energy when held up; both have kinetic energy when moving; as they stop, they both interact with surrounding objects

- Even if you can't see it, the energy could transfer to the surroundings around the pendulum or be converted to some other form of energy within the pendulum.
- The ball has kinetic energy when the ball is moving. When the ball hits the clay, the ball transfers kinetic energy to the molecules of the clay via collision. Similarly, the pendulum could be hitting molecules and transferring energy.
- The molecules of the ball transfers energy to the molecules of the clay
    - *Ask students to explain the process*

Discussion

Revisit the various manifestations of of energy from the brainstorming session in Activity 1. If *potential energy* is not on the list, add the term and what it might mean. In the next investigation, students will analyze factors, such as force and relative position, which affect potential energy. At this point, the discussion should just focus on the word *potential* and what it might tell us about potential energy—energy that could be used.

Possible questions:

- *What does the word* potential *mean?*
- *What does that tell us about what the term* potential energy *might mean?*

Make sure students agree that potential energy is not associated with movement, but is connected with relative positions of objects.. Make sure students also agree that potential energy can be thought of as energy that is being stored in the system of interacting objects, and the amount of energy stored in the system depends on the relative position of objects within the system

Discuss the types of energy previously listed by students and categorize them as potential, kinetic, or evidence of energy transfers.

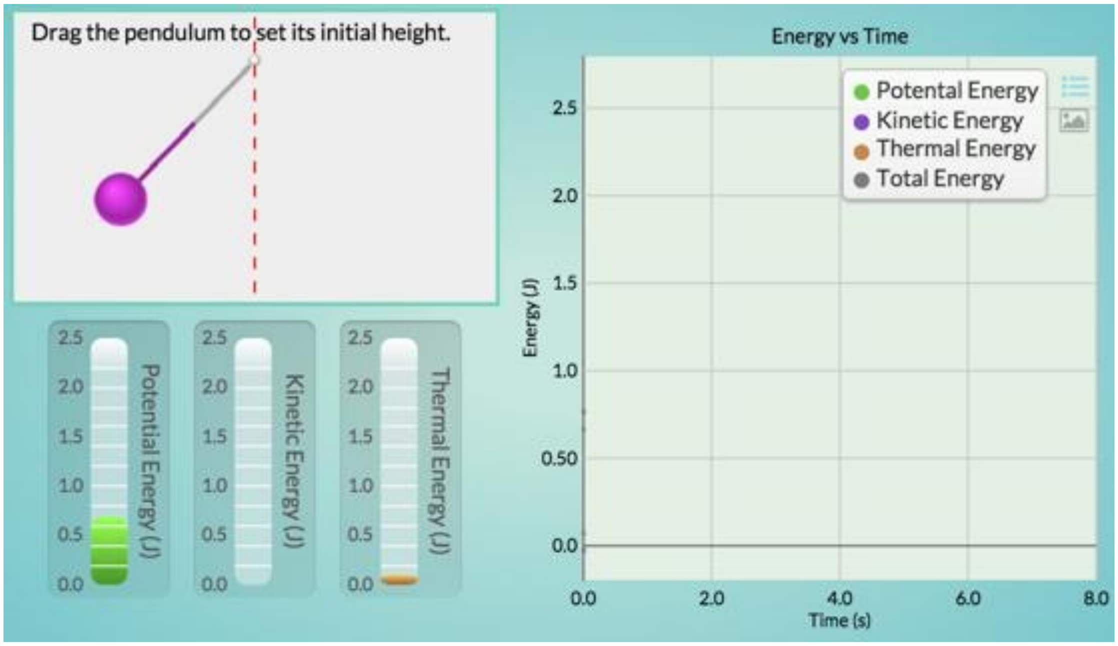
- Kinetic energy: movement of objects, thermal (movement of particles), wind (movement of air), hydro (movement of water), electric (movement of electrons)
- Potential energy: gravitational, magnetic, electrostatic, nuclear
- Evidence of energy transfers: light, sound, heat

Possible question:

What other real-life examples of potential and kinetic energy can you think of?
(Possible examples: hydroelectric power, water towers, pendulums, springs.)

Page title:
Pendulum and energy

Use the simulation to explore what happens to the pendulum's kinetic energy when the pendulum stops swinging. As you run the simulation, test different conditions. Observe changes in potential, kinetic, thermal, and total energy.



Simulation link: http://lab.concord.org/interactives.html#interactives/interactions/pendulumEnergy.json

7. Notice that the energy can start as one form of energy and change into other forms. Identify at least two examples of this from the simulation.

Supplemental content: This question is asking about an energy conversion (when energy changes from one form to another). In the discussion of this question after students have answered it, introduce the term for this idea.

Students are not expected to know or use the term energy conversion in order to answer the question.

Student responses: Students may identify several different energy conversions. Check to make sure students clearly indicate that the type of energy is different. However, it does not matter which object is associated with the energy.

- potential to kinetic
- kinetic to thermal
- kinetic to potential.

8. The energy may have also been associated with one object in the beginning but a different object by the end. Identify at least one example of this in the simulation.

Supplemental content: This question is asking about energy transfer (when energy transfers from one object to another). Note: when talking about energy transfers, physicist try to avoid terms like “move” because the energy is not a concrete object that moves between the objects. Rather, through the interaction of the two objects, the energy of one decreases while the energy of another increases. In the discussion of this question after students have answered it, discuss the definition of the term for this idea.

Students are not expected to know or use the term energy transfer in order to answer the question.

Student responses: Students should indicate which objects are involved, but they do not need to discuss the type of energy.

- Pendulum to air
- Pendulum to surroundings

Discussion

Discuss the questions about changes to energy and introduce the terms energy transfer and energy conversion.

> *Energy transfer* occurs when the energy of one object increases and the energy of a second object decreases through their interaction with each other. An example of energy transfer is when a rolling ball hits a second ball that isn't moving, causing the second ball to move. In that case, kinetic energy was transferred from one ball to the other.
>
> Energy can also *convert* from one form to another. Using a compressed spring to push a car is an example of energy conversion (and transfer). The potential energy of the spring is converted to kinetic energy of the car.

Possible questions:

- *What examples did you include of when the energy changed forms?*
- *Can anyone think of additional examples for when energy changes form?*
- *The name for this idea is energy conversion; what does conversion mean?*
- *Do you think an energy conversion could be reversed?*
- *What examples did you think of for when the energy changes between objects?*
- *This is called an energy transfer; what does transfer mean?*
- *How is* energy conversion *different from* energy transfer*?*
- *Can energy conversion and energy transfer occur at the same time? Provide an example, or explain why not. Does anyone disagree?*
- *Can you have one without the other? Provide an example, or explain why not. Does anyone disagree?*

9. Compare the total energy when the pendulum starts with the total energy when the pendulum stops. What do you notice?

Student responses: Students should note that the total amount of energy when the pendulum starts is the same as the total amount of energy when the pendulum stops.

- The amount of energy doesn't change
- The energy bounces up and down
    - *Ask student what the label is on the graph that bounces up and down. What happens to graph labeled total energy?*

10. Use evidence from the pendulum demo and this simulation to explain what happens to a pendulum's kinetic energy as the pendulum comes to a stop.

Student responses: Students should note that the average kinetic energy of the atoms in and around the pendulum increases, or that the air and pendulum get warmer. The pendulum's kinetic energy is transferred to the atoms in the air and the atoms of the various parts of the pendulum itself. This increases the kinetic energy of the atoms that make up those objects, causing them to be warmer.

- The kinetic energy of the pendulum is converted to thermal energy as the pendulum stops swinging.
  - *Push students to explain how this could happen (collisions with air, friction between the rope and stand).*

Discussion

Ask students to share their conclusions about the simulation.

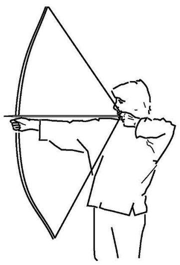
- What are the components/variables of the model shown in the simulation ? (both visible and invisible)
- What are the relationships between those variables?
- How does the model help explain why objects don't move forever?

Possible questions:

- *Was there any setup of the simulation that caused the total amount of energy to change?*
- *Why did the thermal energy increase as the pendulum slowed down?*

NOTE: Make sure students refer to the simulation to support their claims.

Tip: If students have trouble understanding the connection between heat and friction, instruct them to rub their palms together. They should notice their hands warming up. Another example is rubbing an eraser against a table. Students should notice that the spot where the eraser touched the table became warm.



11. When a bow is used, it is important that an arrow is on the string when the string is released. If the string is pulled back and released without an arrow, the bow will likely get damaged and the archer (with popup definition: person who shoots with a bow and arrow) **will likely get hurt. However, if an arrow is used with the bow, releasing the pulled back string makes the arrow fly. Use what you have learned about energy to explain why it is so important to have an arrow on the string**.

Figure 1: Bow and arrow
Credit: Benjamin Crowell
License: Creative Commons ShareAlike 3.0 or higher
Image source:
http://en.wikipedia.org/wiki/File:Bow_and_arrow.jpg

Supplemental content: When the bow is pulled back, there is potential energy associated with the system. When the bow is released, the energy must go somewhere. The energy can go into making the arrow move, or it can go into breaking the bow.

Clarification - Students do not need to use the technical terms ("conserved", "stored", etc.).

Student responses: Students should use the idea that energy must be conserved. Energy can be converted from one form to another, but the total energy in a system cannot change.

- When the bow is pulled back, potential energy of the system increases. When it is let go, it will be converted to either kinetic energy of the arrow, making it move, or into breaking the bow.

12. [drawing prompt] Draw a diagram that shows the conversions of energy from one form to another and how energy is transferred when a bow is used to shoot an arrow.

Student responses: Students' diagrams should indicate that potential energy of the bow is converted to kinetic energy of the arrow.

Concluding the Lesson

Ask students to give other possible examples of energy conversion between potential energy and other forms of energy.

Possible questions:

- *What forms of energy are present in these examples?*
- *What does it mean that energy is conserved?*
- *How is energy conserved in these examples?*

Revisiting the Driving Question
Students may feel that the class has moved away from the driving question about sparks and explosions. Display the driving question for the unit: *How can a small spark start a huge explosion?* Ask students how the activities involving colliding objects relates to this question.

Possible questions:

- *What are some main ideas we have learned about energy so far?*
- *How do you think this might apply to the driving question for this unit?*
- *What questions have we answered?*
- *What questions do we still need to answer in order to explain how a small spark can start a huge explosion?*

NOTE: The driving question should not be answered at this point. Instead, ask students to think about possible connections between the driving question and the activities they have done so far.

Homework: Reading for Activity 1.4
Energy Conservation