Potential & Kinetic Energy Lesson 1: *The Solve*

Educator's Resource Guide: Live Video Phenomenon

The Solve contains two mini lessons: The live video lesson and the animation lesson For the most comprehensive learning experience, conduct both. If you're short on time, choose one. Which lesson?

- For a more structured lesson, choose the animation.
- For a more inquiry-based lesson, choose the live video lesson (the lesson below) and assign the animation for homework.

Objective

In *The Solve*, students will:

1. Observe a phenomenon and conduct investigations to discover the relationship between potential and kinetic energy.

The Activity

Students will view a music video that uses energy transfer in surprising ways and work on drawing conclusions about potential and kinetic energy. They will then create their own Rube Goldberg systems in groups and compare and contrast designs by analyzing the potential and kinetic energy of each. Through this analysis, they will learn the relationship between potential and kinetic energy.

Phenomenon Description

The band OK Go released a music video that uses a single four-minute Rube Goldberg machine demonstrating a series of thrilling potential and kinetic energy transfers in an uninterrupted video shot. Students will conduct investigations to model their own Rube Goldberg systems and draw conclusions about the relationship between potential and kinetic energy.

Time Required: 45–70 minutes

Materials Required

- Video clip
- Student Guide
- Computer with speakers (for projecting video) or headphones (for student viewing on laptops)
- Various materials for students to construct their own Rube Goldberg systems. Potential materials include:
  - Paper towel rolls
  - Masking tape
  - Rulers
  - Marbles

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	○ Plastic cups ○ Books (for adding height) ○ Dominoes ○ Ball options: tennis ball, rubber ball, baseball, lacrosse ball, basketball ○ Small cars ○ Ping-Pong balls ○ String
Safety Considerations	**Science & Engineering Practices**
None	● Developing and Using Models ● Constructing Explanations or Arguments from Evidence

Inquiry Scale: Leveling Information

The Solve can be completed in various settings, including presentation-style, small groups, or individually.

Level 1: Most teacher-driven

View the video clip several times as a class. Discuss the video clip as a whole class. After the first viewing, prompt students with questions to lead them to more observations and invite them to ask questions about what they are seeing. Students will jot down observations in their Student Guide.

Discuss as a whole class how students may want to create a model of the scene and test their ideas about what could be causing this phenomenon to happen.

As a class, test out ideas and record student observations.

Brainstorm together possible explanations based on student testing, using the scientific terms, and then work as a class to label the pictures in the Student Guide.

Level 2

View the video clip several times as a class. Discuss the video clip as a whole class. After the first viewing, students will work with their groups to jot down observations and questions in their Student Guide. Discuss as a whole class how students may want to create a model of the scene and test their ideas about what could be causing this phenomenon to happen. Demonstrate an example that they might test. In their groups, they will test out their ideas together and record their observations. Brainstorm together possible explanations based on their testing, using the scientific terms, and then use their experiences to label the pictures in the Student Guide.

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Level 3: Most student-driven
View the video clip as a class, in groups, or pairs several times. Discuss the video clip as a whole class, and then in student groups. Students will jot down observations and questions in their Student Guide. In their groups, students will brainstorm ideas and create a model of the scene to test their ideas about what could be causing this phenomenon to happen. Groups will then test out ideas and record their observations. Students will brainstorm possible explanations based on their testing, using the scientific terms, and then use their experiences to label the pictures in the Student Guide.

Agenda
Part 1**. Video Clip of Phenomenon** (5–10 minutes)
Differentiation Tip: The video can be viewed as a class, in small groups, or individually.

1. Play the video clip of the phenomenon. *The video clip is awe-inspiring. It's a thrilling example of a large-scale Rube Goldberg system involving potential and kinetic energy transfers! Your students will likely react and want to watch it again. Give students time to react initially before asking them to record observations in their Student Guide.*
2. Students answer questions in Part 1 of their Student Guide. The questioning will encourage students to think analytically about the video.

    Question 1: What was the purpose of the system in the video? What goal did it accomplish? *The system sprayed the singers with paint.*

    Question 2: What was the initial source of energy in the system? *The initial source of energy was a toy car being pushed into a set of dominoes.*

    Question 3: What type of techniques were used to move objects in this video? Jot down three or more observed techniques. *Because of their placement, many objects caused other objects to move. Answers will vary. Answers may include: falling dominoes hit other dominoes to make them fall; gravity caused a tire to roll down a ramp and put the mallet in motion; a fan made air that moved an umbrella that made another object move when the umbrella hit it; a piano dropped from a high place to the floor to break a string that was holding another object in place, so it moved; a shopping cart fell and dumped groceries on a tarp that pulled objects to make them move.*

    Question 4: This system shows examples of something called potential energy (energy stored based on the position of an object) and kinetic energy (energy in a moving object). Where do you think this system shows potential energy? Give at least two examples and explain your thinking. *Encourage students to think about the word* potential *and where they might see energy that is not yet being expressed but is held as "potential." Potential energy is displayed each time objects have the potential to fall (such as a bowling ball up high, dominoes that are propped upright but haven't yet fallen, or a tightened spring).*

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Question 5: Where do you think the system shows kinetic (moving) energy? Give at least two examples and explain your thinking. *Encourage students to think about where they see evidence of objects moving for examples of kinetic energy. Answers will vary. Answers may include a bowling ball moving down a ramp; bottles rolling; an umbrella moving across the floor; and dominoes toppling.*

Have students share their guesses about examples of potential and kinetic energy. When they are done, provide students with the definitions for potential and kinetic energy. They will be applying this information to the next part of the activity:

- *Potential energy is stored energy based on height.*
- *Kinetic energy is the energy of motion.*

Part 2**. Let's Figure It Out!** (30–35 minutes)

1. As guided by their Student Guide, students will first choose a task they'd like their Rube Goldberg machine to accomplish. *Task ideas include ringing a bell, dropping a pencil into a cup, dropping sprinkles onto a cupcake, popping a balloon, turning the knob on a radio, adding water to a plant, dropping fish food into a fishbowl, closing a book, or turning a light on or off.*
2. Students will design their own Rube Goldberg system and draw their final model in their student guide. Students will be using the materials at their table to try to recreate a version of the phenomenon in an effort to understand what caused their observations. Set out a variety of materials for them to use to create a model on which they can test their ideas. Having a variety of random items provided on their desks in a box will work if you have similar items to provide for each table. You may also think about providing some basic items to each group and then have a supply area from which they can choose other specific items that may work well for their models. Students can record all ideas, illustrations, and test results in this section of their Student Guide. *Many times, students want to keep their projects even though it may not be possible. One suggestion is for students or teachers to take photographs or video clips to record their projects for posterity.*

3. Initially, give students 10–15 minutes to experiment with the materials. Walk around the room and observe students' models. If students seem stuck, prompt them to consider delegating the design of events.
4. *For example,instead of the whole team working together on the same event at the same time, teams can divide the tasks of designing one of the events and then collaborate to design energy transfers to connect one event to the next.*
5. For the remaining 15–25 minutes, students can finalize their models. Continue walking around, listening to their conversations and observing when they may be making connections to the concepts of potential and kinetic energy. If a group asks a question, try to ask them a question in return to get them actively thinking. Examples: What do you think that means? What else did you notice about that? Do you need to consider changing the amount of potential or kinetic energy in the system? What if you tried…? How could you show that idea? What evidence do you have to support that idea?

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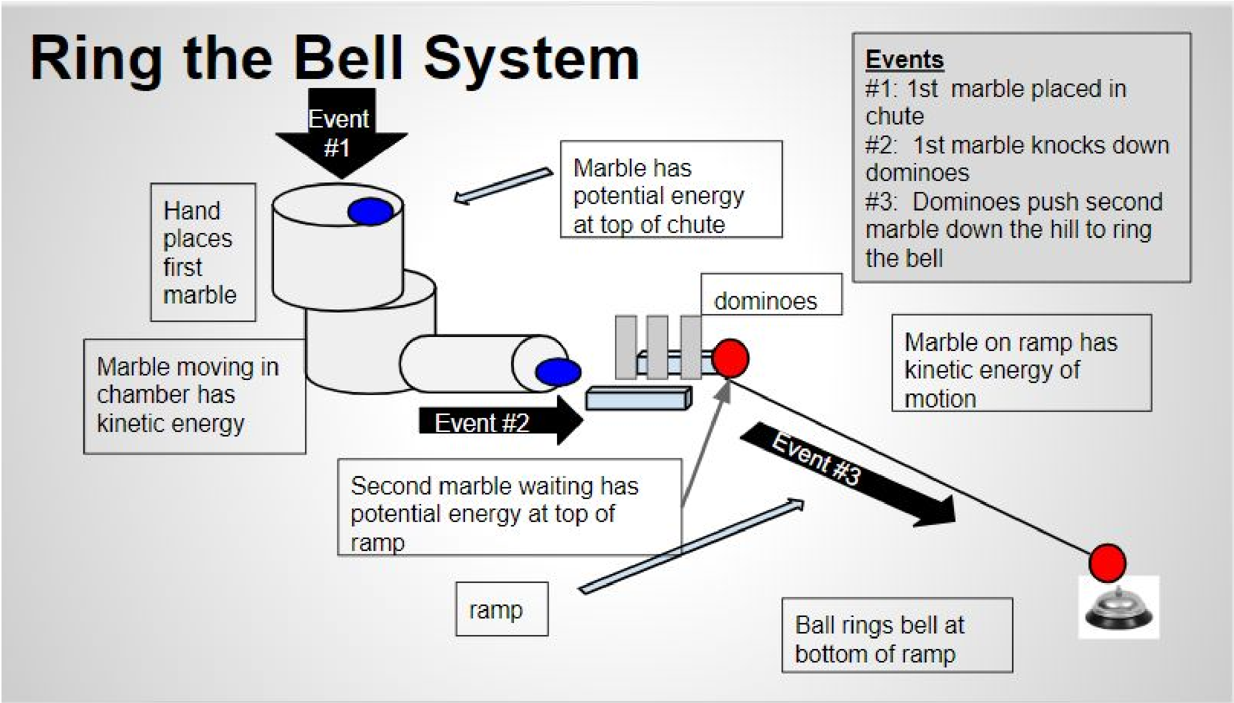
Sample student diagram



Sample student events Individual Event Videos (Ring a Bell)

- Video 1
- Video 2
- Video 3

Part 3. Connect (20–25 minutes)

1. Students demonstrate their model in action and complete the table of potential and kinetic energy observations for each model. *Teacher Note: To capture student work, consider taking photos or videos if possible. These can be referred back to when comparing designs.*
2. Students use their observations from the video clip, their models, and terms and definitions in their Student Guide to explain what is happening and label the images with the terms.

Scientific Terms:

- Potential Energy: Stored energy related to an object's position
- Kinetic Energy: The energy of an object expressed as its motion
- Speed: The rate at which something moves
- Height: The vertical distance between an object and the ground

Answers may vary. Encourage students to make connections with all of the terms in their explanation.

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Part 4**. Comparing Designs**

Students will compare team designs and note their observations in their Student Guide. Note: If doing this virtually, students can share videos of their final projects, or projects can be shared during a virtual meeting time.

Possible student answers: What do you notice about the use of **potential energy**? How many instances of potential energy do you see in each model?

How did the team use the **kinetic energy** that was transformed from potential energy?

Example Answers:

Team Task Name	**Potential Energy Observation**	**Kinetic Energy Observation**
Ring the Bell	Car at the top of the first ramp	Car rolled down and bumped the large ball to make it ring the bell
Push in a Tack	Shoe tied by shoelace to the top of a ring stand	Shoelace was untied by falling clamp, and the shoe dropped onto the tack

Conclusions Questions: *Example answers:*

1. Which team had the model that started with the **most potential energy**? How do you know?

Answers will vary. *Students should indicate the model with the starting height the highest distance from the floor. The greater the distance between the floor and the starting height, the more potential energy the model provided at the start (this connection is deduced from synthesizing the terms used in Part 3).*

2. What do you notice about the relationship between height and potential energy?

Answers will vary. *The greater the height at the start, the more potential (stored) energy is put in the system, so the model may be able to have very complex events because its height gives it a lot of potential energy at the start.*

3. Which team had the model that had the point of the **greatest kinetic energy**? How do you know? Was it the same team that you named in question 1? Why or why not?

Answers will vary. Students may note that the model with the greatest starting height may also have a noticeably high point of kinetic energy near the end point, or the point that is the lowest height position. Otherwise, an acceptable answer is one that notes a point of particularly high kinetic energy (speed).

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4. Based on your answers to questions 1–3, what conclusion can you draw about the relationship between potential and kinetic energy?

Answers will vary. Students may note that the model demonstrates more than one relationship between kinetic and potential energy. The most expected conclusion is that if a system has a high amount of potential energy at the start, a high amount of kinetic energy is observed as potential energy is converted to kinetic energy as evidenced by the number and complexity of events to accomplish the task. Less obvious relationships include that when potential energy is high in a rest position (a great amount of stored energy), kinetic energy is at its lowest (no motion in this rest position). Less obvious but also true is that when an object is in motion from a rest position, such as when a ball rolls down a ramp from a rest position, the object gains speed while losing height, which demonstrates a decrease in potential energy as kinetic energy increases (an inverse relationship).

Annotated Drawings

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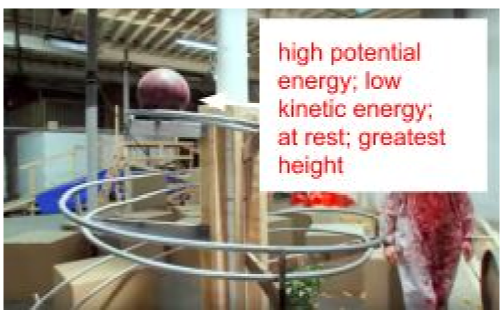
<tr><td>
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Part 5. Quiz: Check for Understanding (5–10 minutes)
Differentiation Tip: This can be done in groups, pairs, individually, or more formally as an online quiz.
Students complete the exit ticket to check for understanding. This can be done online by selecting the **Quiz** button in Lesson 1 or on paper in the Student Guide. Answers are in the Answer Key section below.

Quiz:

1. A ball at rest at the top of a hill has _______.
    a. kinetic energy
    b. motion
    c. speed
    d. potential energy
2. The ball is pushed so it begins to roll down the hill. It now has _______.
    a. kinetic energy
    b. a rest position
    c. more potential energy
    d. no energy
3. What factors can increase the speed of a ball rolling down a hill?
    a. Increased potential energy
    b. Increased kinetic energy
    c. Both A and B
4. What is potential energy?
    a. The amount of energy an object could have if it tried hard enough
    b. Moving energy
    c. Active energy
    d. Stored energy
5. What is kinetic energy?
    a. Stored energy
    b. Moving energy
    c. Potential energy
    d. All of the above
6. A roller-coaster car is at the top of the hill, one is at the middle of the hill, and one is at the bottom of the hill. Which has the most potential energy?
    a. The car at the bottom of the hill
    b. The car in the middle of the hill
    c. The car at the top of the hill
    d. All the cars have zero potential energy.

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