THE REIMAGINED CLASSROOM

Lesson: Conservation of Energy with Dropper Poppers

OBJECTIVE

Using a variety of contexts, this lesson will allow students to discover that energy is transformed into different types and not created or destroyed.

Students will be able to:

- Define and use in a discussion or short answers the following terms: potential energy, kinetic energy, elastic energy, the law of conservation of energy
- Calculate potential energy and kinetic energy in problems related to conservation of energy
- Explain the law of conservation of energy in terms of potential and kinetic energy
- Apply the law of conservation of energy to a scenario that involves potential energy and kinetic energy

MATERIALS

- Dropper popper (1 per student group)
  - Purchase **here** or **here**
- Ping-pong ball (1 per student group)
- Meter stick (1 per student group)
- Stopwatch (1 per student group)
- Electronic balance/scale
- **Student lab instructions**
- **CER** template
- **POER graphical organizer**
- Pencil (1 per student)
- Calculator (1 per student group)
- Safety goggles or other eye protection
- **Media folder**

TEACHER PREP

1) Practice using the dropper popper and the ping-pong ball prior to class to confirm the best way to get maximum height.
2) If possible, take some of the measurements before class in order to have an estimate of appropriate numbers.
3) If you would like to do this lesson outside, find an open space that is paved for students to set up dropper poppers.
4) Review the media folder for video examples of the investigations and other useful resources.

SAFETY PRECAUTIONS

- Students should wear eye protection when using dropper poppers, especially in combination with the ping-pong ball.
- Make sure that students do not lean over the dropper popper, to avoid the ping-pong ball flying into their face.
- Students should try to have the dropper popper as centered as possible to allow for a straight-up direction of movement and not an angled direction of movement.

VOCABULARY

Potential energy
Kinetic energy
Law of conservation of energy
Elastic energy

GUIDING QUESTIONS

1) What do different forms of energy look like?
2) How is energy conserved?
3) How can energy be transferred into different forms?
4) How can we calculate kinetic and potential energy?

LESSON HIGHLIGHTS

- Warm-Up: Invitation: Discrepant event demonstration using a dropper popper and a ping-pong ball
- Mini-Lesson: Exploration: Learning the terminology and basic formulas they will need for this lesson and this unit regarding energy
- Group Work/Content Practice: Concept Invitation and Application: Collecting data that will help them explain the concepts of the lesson based on evidence
- Share: Reflection: Synthesizing knowledge and reflecting on how their ideas have changed

INVITATION | 10 minutes

Invitation

- Students will complete a POER (predict, observe, explain, and revise) using a **graphical organizer**.
- Before performing the demonstration, show students the dropper popper. Invert it and allow students to see how it works. You can even allow student volunteers to touch and manipulate it for the class. Show students that the dropper popper can be manipulated two different ways and both ways will result in a similar height when it pops.
- Then show them the ping-pong ball and explain that you will place the ping-pong ball on the inverted popper.
- Students should record their predictions about what will happen to the popper and the ping-pong ball.
- Then perform the demonstration for the students. The ping-pong ball will fly very high, as much as several stories of a building. Be prepared for it to hit the ceiling if performing indoors. Alternatively, if it is relatively easy for you to access an open, paved area, you can take the students outside for class. The demonstration will happen fast, so you may need to do it a few times for students to complete their observations. You may also need to prepare students by prompting them to be ready to make and record their observations.
- Students should then complete the explanation portion of the POER. Encourage them to do the best they can with what they know so far and remind them it is okay if they do not have the complete answers just yet, as this lesson will elaborate on these concepts and by the end they will have a full scientific explanation with reasoning. Do not discuss as a class yet or share the correct responses.
- Tell students the revision portion of the POER will be completed at the end of class.

EXPLORATION | 20 minutes

Exploration

Instruct students to use computers to open **this link** to access a reading and a simulation on the conservation of energy.

They will only read the first section, titled “Mechanical Energy and the Conservation of Energy.” The section includes the Virtual Physics and Grasp Check that will have students explore the concepts of energy using the Energy Skateboard PhET. Students should answer the 4 questions in the Grasp Check using the PhET. This can be done individually, in a group, or as a Think-Pair-Share. Discuss the responses for the 4 questions. At this point, students should just be beginning to understand the relationships between potential and kinetic energy.

Remind students that there is a final paragraph in the section after the Grasp Check. In other words, they should stop reading when they see the heading “Calculations involving Mechanical Energy and Conservation of Energy.”

GROUP WORK/CONTENT PRATICTICE | 50 minutes

Concept Invention
Students will complete a lab. You can access **student directions here**.
They should initially measure the following:
- The mass of the dropper popper
- The exact distance the popper is compressed when it is inverted

Students should then pop the dropper popper 10 times and record the following for each trial:
- The maximum height of the popper (best done by holding a meter stick directly behind the popper)
- The time it takes for the popper to leave and return back to the ground (using a stopwatch, students will start when it pops and stop when it hits the ground)

Afterwards, students will calculate the average maximum height and the average time. Using this data, students can then calculate the average velocity and average acceleration. Remind students that they will need to multiply the average maximum height by 2 in order to allow for the total distance traveled by the popper.

Students can then calculate the potential energy using the formula PE = mgh using their mass of the popper and the average maximum height.

In order to calculate the kinetic energy of the popper just before it reaches the ground, students first need to calculate the velocity of the popper just before it hits the ground. At this point of the movement is when the dropper popper will have the greatest kinetic energy. To calculate the velocity just before the popper hits the ground, use the formula $V_f^2 = V_i^2 + 2ad$.

The initial velocity should be zero, and students should have the total distance and average acceleration from their previous calculations. Once this final velocity has been obtained, students can calculate the kinetic energy with the formula $KE = \frac{1}{2} mv^2$ using the final velocity.

Then have students compare their potential energy and kinetic energy and answer the following questions with their group:
- How are the values calculated for PE and KE related?
- How is energy either lost or contributed to cause the PE and KE values to not be the same?
- How does the elastic energy of the spring affect the PE and KE?
- What if the material of the dropper popper allowed for more elastic potential energy to be stored? How would this affect the maximum height of the dropper popper and the KE?

Application
After students have collected their data and answered the questions, show them the first 42 seconds of **this video by Physics Girl**. Ask students if they can explain what is happening in the video based on what they have observed in the initial demonstration with the dropper popper and the ping-pong ball, as well as what they measured in the lab activity. Allow for some ideas to be discussed without confirming accuracy.

Then show more of the video until 2:09. Ask each group to complete a **CER** (Claim, Evidence, Reasoning) argument for why the ping-pong ball went so high. They can use evidence from their observations, the Energy Skateboard PhET, lab, or the short video clips. Allow for the groups to share and discuss as a class.

Differentiation
Support:
- If the trampoline example from the Physics Girl video was not clear, **here is an additional simulation a trampoline** that narrates the scientific concepts, including the potential and kinetic energy. It includes bar graphs of kinetic and potential energy due to gravity and potential elastic energy that show how the amount of each change with a person jumping on the trampoline.
- It is possible to scaffold the lab activity by performing it as a whole class and asking for volunteers to observe the height. Collect the data as a whole class by projecting the computer screen. This will also speed up the activity. However, students will lose the opportunity to manipulate, experiment, and construct individually or in small groups.
- Provide hard copies or electronic copies of tables that students can complete, so that they do not have to create their own.
- Provide templates for students to complete for the POER and the CER, either as hard copies or electronically. See examples provided.

Extension:

- For the lab portion, students can determine the PE from the elastic energy of the popper and the spring constant for the material. Assume that the difference between the maximum potential energy due to gravity is equal to the elastic potential energy because at both points there is no kinetic energy and the law of conservation of energy applies. Students can further calculate the spring constant for the material of the dropper popper by using the formula $PE = \frac{1}{2} kx^2$ where x is the distance of the compression of the inverted dropper popper.
- If there is time or if you have students especially interested in the topic, you can show the remaining 1:24 of Physics Girl's "Stacked Ball Drop" video, which describes how the concept is applied to a supernova.
- Try the triple-stacked ball bounce or purchase an astroblaster online. It is a stack of balls with a rod to help with the alignment. Alternatively, you can make your own. Allow students to drop each of the balls independently and measure the height that each bounces. Then measure the change in heights of each of the balls when stacked. Ask students to computationally show the conservation in energy as it relates to kinetic and potential elastic energy.
- Ask students to think of other examples of conservation of energy or to design their own devices that demonstrate the conservation of energy. They should be able to explain how energy is conserved in terms of the kinetic and potential energy.

Assessment

Throughout the lesson, ask formative assessment questions by circulating through the room to check for understanding and confirm students are progressing in the construction of their knowledge of the law of conservation of energy. Ask for students to explain what they are observing or measuring and how it relates to the conservation of energy. Remind them to think about other factors that may impact the conservation of energy, such as the elastic of the dropper popper or the elastic energy between the balls. Ask them to explain how the energy is transformed and how the value of different types change in relation to each other.

Ask students to submit their responses to the questions in the "Reflect" portion of the lesson so that you can read their responses and provide feedback, as well as address any misconceptions. These can be done by collecting the papers or having students submit electronically.

Additional practice problems can be given for homework, either from a textbook or an open source textbook such as **this one** with several practice problems. Additional critical thinking problems can be found **here** and additional math problems can be found **here**.

REFLECT | 10 minutes

Reflection

Individually ask students to synthesize their understanding of the law of conservation of energy as it relates to potential and kinetic energy. Time permitting, this can be done as a Think-Pair-Share.

Instruct students to look at their initial POER, specifically analyzing their responses. Students should then draw a line underneath their initial responses and write a new, revised response that incorporates everything they have learned today.

Finally, have students identify by looking at their initial and revised responses how their understanding has changed and to identify areas that they still may not be entirely clear about.

CCSS ELA

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.
WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

CCSS MATHEMATICS

MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

NEXT GENERATION SCIENCE STANDARDS

HS-PS3-1 Energy: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flow in and out of the system are known.

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

HS-PS3-3 Energy: Develop, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Disciplinary Core Ideas
PS3.A Definitions of Energy
PS3.B: Conservation of Energy and Energy Transfer

Science and Engineering Practices
- Using Mathematics and Computational Thinking
- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Engaging in Argument From Evidence

Crosscutting Concepts
- Systems and System Models
- Energy and Matter
- Cause and Effect