All Work and No Play

Work and Energy

K20 Center, Allison Shannon
Published by *K20 Center*

Grade Level	9th – 12th Grade	**Time Frame**	1-3 class period(s)
Course	Physical Science, Physics	**Duration**	150 minutes

Essential Question

What effect does increasing the potential energy of an object have on the work it does on another object during a collision?

Summary

In this lesson, students will explore the conservation of mechanical energy and how it relates to work during collisions. They will activate prior knowledge using the How I Know It strategy to review key vocabulary such as potential energy, kinetic energy, and work. In groups, students will follow a guided investigation using marbles and toy cars to test their hypotheses. They will graph their data and apply their understanding to a real-world collision scenario.

Snapshot

Engage

Students are challenged to list as many things that they already know about potential energy, kinetic energy, and work.

Explore

Students make a hypothesis based on the essential question and carry out a structured investigation to test it.

Explain

Students state their hypotheses, explain the investigation, and state their conclusions.

Extend

Students calculate the amount of force applied to the car and create graphs that shows the effect of increasing potential energy on the force applied to the car and the distance it traveled.

Evaluate

Students are given a scenario of a car involved in a rear collision. Students will figure out how far the car will travel and if a nearby pedestrian is in danger.

Standards

ACT College and Career Readiness Standards - Science (6-12)

IOD202: Identify basic features of a table, graph, or diagram (e.g., units of measurement)
IOD302: Understand basic scientific terminology
IOD304: Determine how the values of variables change as the value of another variable changes in a simple data presentation
IOD403: Translate information into a table, graph, or diagram
IOD503: Determine how the values of variables change as the value of another variable changes in a complex data presentation
SIN301: Understand the methods used in a simple experiment
SIN401: Understand a simple experimental design
SIN503: Determine the experimental conditions that would produce specified results
EMI401: Determine which simple hypothesis, prediction, or conclusion is, or is not, consistent with a data presentation, model, or piece of information in text
EMI502: Determine whether presented information, or new information, supports or contradicts a simple hypothesis or conclusion, and why

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-PS3-1: 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 flows in and out of the system are known.
HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Oklahoma Academic Standards (Physical Science)

PS.PS3.1 : 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 flows in and out of the system are known.
PS.PS3.3 : Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*

Oklahoma Academic Standards (Physical Science)

PH.PS2.3.DCI.2: Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
PH.PS3.1 : 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 flows in and out of the system are known.
PH.PS3.3 : Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*

Attachments

- Lab Investigation—All Work and No Play - Spanish.docx
- Lab Investigation—All Work and No Play - Spanish.pdf
- Lab Investigation—All Work and No Play.docx
- Lab Investigation—All Work and No Play.pdf
- Lesson Slides—All Work and No Play.pptx

Materials

- Lesson slides (attached)
- Lab Investigation handout (attached; stapled; one per student)
- Toy car (one per group)
- Ruler (one per group)

- Meter stick (one per group)
- Marbles (five marbles per group)
- Books for stacking
- Electronic scale(s)
- Graph paper (one per student)
- Calculator (one per student or group)
- Sticky notes (one per student)

Preparation

Exploration Prep

To ensure the challenge works properly, make sure the ruler has a groove or track for the marbles to roll down smoothly. Also, check that the toy cars are in good condition and roll straight without veering off course.

Prior Knowledge

They will need a prior knowledge of the three equations:

$PE = mgh$

$KE = 1/2\ mv^2$

$W=Fd$

Consider unhiding **slide 6** if students need a review.

10 minutes

Engage

Use the attached **Lesson Slides** to guide the lesson. Introduce the lesson using **slide 2**.

Display **slide 3** and have students work in pairs. Point out the terms on the slide: *potential energy*, *kinetic energy*, and *work*. Explain that they will use the How I Know It instructional strategy to write everything they know about these terms and how they know it. Pass out the **Lab Investigation** handout to each student. Direct them to the first page. Encourage them to think back to previous science classes, activities, and experiments for their response.

The How I Know It strategy requires the students to think deeply about how they know the terms. If students can't really think how they know or remember these terms, lead a class discussion and start drawing those experiences and knowledge out as a group.

Teacher's Note: Make It A Challenge

To encourage participation, turn this into a challenge to see how much the students can remember and explain about the key terms.

After using the How I Know It strategy, have each pair share what they came up with.

Take time to clear up any misconceptions by reviewing the terms as needed. Then, have pairs team up to form groups of four for the next part of the lesson.

50 minutes

Explore

Display **slide 4** and share the essential question: “What effect does increasing the potential energy of an object have on the work that is done on another object during a collision?”

Instruct groups to collaborate for a few minutes and write a one-sentence hypothesis on their handouts. Allow groups to share their hypotheses.

Display **slide 5** and go over the lesson objectives with the class.

Show students the following materials: five marbles, a toy car, a ruler, a meter stick, books for stacking, and an electronic scale.

Display **slide 7**. Inform the students that they will use the materials to complete an investigation that will test their hypotheses and answer the essential question. Make sure the students know to gather quantitative data. Put students into groups of 2–4 students.

Teacher's Note: Investigation

The idea is for students to roll the marbles down the ramp to collide with a waiting car at the bottom of the ramp. Through several trials, students will increase the potential energy and measure the distance that the car travels each time. To increase the potential energy, students may increase the height of the ramp or increase mass by using more marbles. The Marble Energy Lab from The Physics Classroom is a variation of this.

Display **slide 8** and have students refer to the next section of their handout. Instruct each group to make a list of all the variables that can be measured when potential energy, kinetic energy, and work are involved. Also encourage them to make a list of variables they should keep constant.

Display **slide 9**. Inform students they will be creating a ramp from the ruler and rolling marbles down the ramp to collide with the toy car. They will repeat this investigation with 1, 2, 3, 4, and 5 marbles. Have students follow the steps for Procedure A on their handout and record the results in the data table. Students will need to answer the questions on the handout after they have completed the investigation.

25 minutes

Explain

Display **slide 10** and introduce the [3-2-1] instructional strategy and have each group record three things they learned from their investigation, two questions they have, and one thing they found interesting on their handout. Have volunteers share with the class what they recorded.

Direct students to the next section on their handout. Explain any sources of error for the experiment and address parts of the procedure that could be refined.

Display **slide 11** and discuss the following question as a class: "In this investigation, how does potential energy eventually become the work that is applied to the second car?"

Call on volunteers to answer and explain their reasoning to the question.

Possible Student Responses

Students should find something similar to the following: The potential energy at the top of the ramp becomes zero at the bottom of the ramp, and the car (marbles) has full kinetic energy as it begins a horizontal roll. When the car collides with the other car at rest, it transfers its kinetic energy to the other car as work by applying a force to the car and moving it some distance.

Not all of the kinetic energy becomes work (some transfers as heat and sound) on the second car, but for the purpose of this lesson, have the students assume that all the kinetic energy is transferred as work. Work is actually equal to the change in kinetic energy. Again, have the students assume that the final kinetic energy will be zero.

30 minutes

Extend

Display **slide 12** and instruct students to calculate the potential energy of each of their trials. Direct students to the first analysis of their handout. Pass out a calculator to each student or each group.

Display **slide 13**, ask the students the following question: "Assuming that all the potential energy is gone at the bottom of the ramp, what is the kinetic energy the car possesses?" (The answer is equal to the initial potential energy.) Pause and allow students to respond.

Next ask the students the next question: "Assuming that all of the kinetic energy becomes work done on the second car, what force was placed on the second car?" Pause and let students respond.

Teacher's Note: Equations

Students will need to set KE = W so their equation will be 1/2 mv2 = Fd (d is the distance the second car traveled after the collision).

Instruct students to calculate the force of the car as the potential energy increases.

Display **slide 14**. Now students are ready to create the graphs. Have them graph the increasing potential energy vs. the force applied on the car and the distance the car traveled. Students will need two y-axis (one on left and one on right, labeled force and distance respectively), and the potential energy will be on the x-axis. Provide students time to work on their graphs.

Once the students have finished their graphs, discuss the trends they notice in the graph. Consider reviewing independent and dependent variables.

Ask students to separate from their groups so they can work individually for the Evaluate section of the lesson.

Optional Velocity Activity

The students may also calculate the velocity that the car has at the bottom of the ramp (at the point that potential is zero).

The equation is: v=v((2Fd)/m)

10 minutes

Evaluate

Display **slide 15**. Read the students the following scenario: "You are sitting at a stoplight at the bottom of a hill. A car at the top of the hill has brake failure. It is freely rolling down the hill and will collide with the rear of your car. The car is 1245 kg (similar to yours), the height of the hill is 155 m and it collides with your car applying 3255 N of force. A woman is pushing a stroller 600 m in front of you. When your car lurches forward, will it strike the woman and the stroller?"

Possible Student Answer

Students will calculate their distance traveled. Their answer should be 582 m. They will stop just shy of the woman.

Have students complete an Exit Ticket. Give students a sticky note and instruct them to write yes or no (indicating "yes, it will hit her" or "no, it will not"), followed by the distance their car will travel. Have them stick the note to your door on the way out. Make sure they put their name on the note.

Resources

- The Physics Classroom. (2009). *Marble energy lab: teacher's guide*. https://www.physicsclassroom.com/getattachment/lab/energy/e4tg.pdf
- K20 Center. (n.d.). 3-2-1. Strategies. https://learn.k20center.ou.edu/strategy/117
- K20 Center. (n.d.). Bell ringers and exit tickets. Strategies. https://learn.k20center.ou.edu/strategy/125
- K20 Center. (n.d.). How I know it. Strategies. https://learn.k20center.ou.edu/strategy/144