The Power Play: Kinetic vs. Potential

(4-5 days)

Authors

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SUBJECT/GRADE LEVEL

Subject Area: Science, STEAM

Grade Level: 8th grade/High School

Materials

Experiment 1 for each group ping pong ball, partially filled bag (or something similar), measuring tape or meter stick

Experiment 2 Balloons filled with 50 grams and 200 grams of sand, craft foam, measuring tape or meter stick

Experiment 3 marble, track, paper, Something to elevate track, measuring tape or meter stick

Marble Roller Coaster blank paper, paper towel (toilet paper) tubes, masking and/or painters tape, scissors, marbles, ruler, stopwatch, books (for height) and protractor (optional).

Data Sheet/Worksheet: Observation and question worksheet and answer key

Simulation: KE Simulation

Marble Roller Coaster Rubric

STANDARDS

Next Generation Science Standards

Middle School Standards:

- MS-PS3-1 Construct and interpret graphical displays of data to describe the relationship of kinetic energy to the mass of an object and to the speed of an object
- MS-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- MS-PS3-5 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.

High School Standards:

- HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- 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 the given constraints to convert one form of energy into another form of energy.

Mathematics Standards | Common Core State Standards

Middle School Standards:

- 7.RP.A.2 Recognize and represent proportional relationship between quantities.
- 8.FA.3 Construct and interpret graphical displays of data to identify linear and nonlinear relationships.
- 6.RP.A.1 Understand the concept of ratio and use the ratio language to describe a ratio relationship between two quantities.

High School Standards:

- G-MG 3 Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).
- S-IC 5 Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

English Language Arts Standards | Common Core State

Middle School Standards:

- SL.8.5 Integrate multimedia and visual display into presentations to clarify information, strengthen claims and evidence and add interest.
- RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

High School Standards:

- SL.9-10.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively
- SL.11-12.1 Initiate and participate effectively in a range of collaborative discussions (one on-one, in groups, and teacher-led) with diverse partners on grades 11–12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

- SL.9-10.4 Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
- SL.11-12.4 Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.
- RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

LESSON OBJECTIVE(S)

- Students will be able to define and differentiate kinetic and potential energy through written explanations and visual representations.
- Students will be able to calculate kinetic energy using the formula $KE = \frac{1}{2}mv^2$ and explain how changes in mass affect kinetic energy.
- Students will be able to explain how changes in acceleration influence kinetic energy by using the formula $KE = \frac{1}{2}mv^2$ and analyse the results of their acceleration experiment.

CAREER CONNECTION(S)

Mentor Background: Dr. Jeff Carroll is a team leader in the U.S. Army Research Laboratory's Power Components Branch. Dr Carroll has more than 35 years experience in experimental nuclear physics and has published over 140 peer-reviewed journal articles. Before ARL he was a Professor of Physics for 15 years. The emphasis of the team at ARL focuses on learning more about basic energy-release mechanisms that may, in the future, support new types of power sources. In the near term, the main impact is fundamental in providing the first evidence for this effect that can be used to evaluate theoretical models to understand the process, and new experiments are being prepared to characterize the process further. In the long term, the researchers hope that this mechanism may provide a practical means of providing a new type of batteries and power sources for Army needs.

STEM Careers:

Physicist, Nuclear Physicist, Mechanical Engineers, Civil Engineers, Aerospace Engineers, Renewable Energy, Nuclear Engineer

ENGAGEMENT

Brief Description: Show students a roller coaster simulation and complete a whole group activity with a balloon and ball drop.

Procedures:

Hook (5 Minutes):

- Introduce potential and kinetic energy with a short roller coaster video. An example can be found here.
- Ask students while watching:
  - "What types of energy do you think are happening in the video?"
  - "What do you notice about the height and the speed of the car (Cart?)

Whole Group Balloon Drop/Roll Experiment (10-15 Minutes):

- Show students two balloons with different masses.
  - Ask Students to predict which one will hit the ground first and why.
- Drop two balloons of different masses from the same height.
  - Discuss student prediction accuracy and why/why not their prediction was/was not correct.
- Invite students to jump in place to demonstrate kinetic energy transfer.
  - *When they are at the top of their jump, they feel the potential energy caused by gravity pulling them towards the ground. When they hit the ground, some of the kinetic energy of their fall is transferred into the floor, while some is transferred back to their body.*
  - Introduce Potential and Kinetic energy vocabulary.
- Introduce a ramp (ramp can be made out of books or other materials around the classroom).
  - Ask students to predict which ball they think will be the fastest and why.
- Let both balls roll down the ramp at the same time.
  - Discuss student predictions.
  - Have students identify where potential and kinetic energy were present.

Transition:

Move to exploration with a statement such as: *"We are going to dive deeper into potential and Kinetic energy and learn how to calculate and compare them using real data from your own experiments!"*

EXPLORATION

Brief Description: Students will perform three experiments to demonstrate potential and kinetic energy.

When the kinetic energy of an object changes, energy is transferred to or from an object. A more massive falling object has more kinetic energy before a collision than a lighter object dropped from the same height.

Procedures: (30- 40 min)

Experiment 1: Through this experiment, students will explore the difference between potential and kinetic energy by observing the effects of a ball dropped from 1 meter high.

Give each group a ping pong ball, and a partially inflated bag (or something similar) and a measuring tape/meter stick. Each student should have their own lab worksheet.

1) First Drop
    - Carefully drop a ping pong ball straight down onto a flat hard surface from a height of 1 meter.
    - Observe what happens to the object upon impact. Record detailed observations in your data table. *When the ball collides with rigid material the ball can deform slightly; some of its energy from its fall is held momentarily as potential energy in its deformation. As the ball regains its shape, it pushes against the rigid material and bounces itself back into the air. In this case kinetic energy is transferred back into the ball.*
2) Second Drop
    - Carefully drop a ping pong ball straight down onto an inflated bag (or some similar material) from a height of 1m.
    - Observations what happens to the object upon impact. Record detailed observations in your data table. *When the same ping pong ball collides with a semi-inflated bag, the ball sinks into the bag, causing the bag to deform. The bag is able to absorb and retain all of the ball's kinetic energy, so the ball does not bounce. All kinetic energy has been transferred to the bag, resulting in deformation of the bag's shape.*

Experiment 2: Through this experiment, students will explore how mass changes the potential and kinetic energy by observing the effects of dropping different weighted balloons. *The heavier the object, the more potential energy and therefore the more Kinetic energy because* $PE = KE$ *and* $PE = mgh$.

Give each group balloons weighted with **50g** and **200g** of sand and a sheet of craft foam (or something similar) and a measuring tape/meter stick and a data sheet. Each student should have their own lab worksheet.

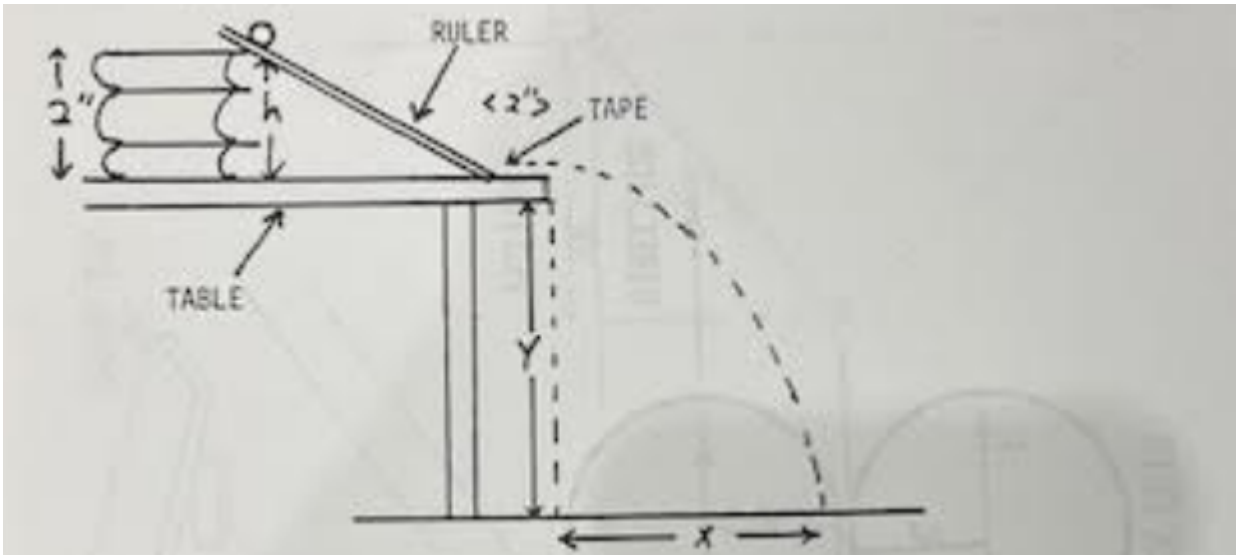
1) First Drop
    - Carefully drop the 50g balloon from a height of 1m straight down onto the prepared surface.

- Observe what happens to the object upon impact. Record detailed observations in your data table.

2) Second Drop
   - Carefully drop the 200g balloon from a height of 1m straight down onto the prepared surface.
   - Observe what happens to the object upon impact. Record detailed observations in your data table.

The heavier balloon will have more deformation since it has greater PE due to the increase in mass. If the students have trouble seeing the difference, have them leave the balloons in place when dropped so that they can compare them.

Experiment 3: A marble is placed further up an elevated ruler and released to prove that the potential energy increases as it is moved up the ruler. *The potential energy is converted into kinetic energy. As the potential energy increases with the increase in height ($PE = mgh$) the marble strikes the floor further horizontally.*



Drop the marble from the edge of the table, and make a mark on a sheet of paper taped to the floor where it falls. Now release the marble from 3", 6", 12" marks on the ruler, and again note where they strike the floor, marking a sheet of paper taped to the floor. Repeat the measurement three times to check. Record the distance the marble travels horizontally from the edge of the table to the point where it strikes the floor.

The marble has potential energy as it is held at the top. This potential energy is converted into kinetic energy as the marble rolls down the ruler and along the table. The marble leaves the table horizontally, so it has no vertical motion. Since we can separate vertical and horizontal motion, it always takes the same time to reach the floor from the table. The potential energy increases as we move the marble up the ruler. This gives a larger kinetic energy, and the additional horizontal velocity resulting makes the marble travel farther horizontally before striking the floor.

EXPLANATION

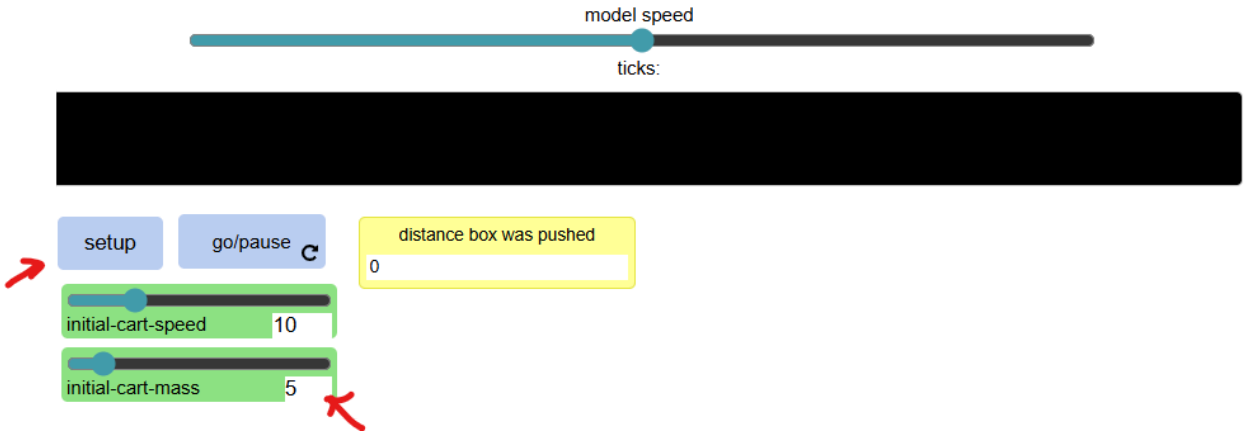
Brief Description: Students will calculate potential and kinetic energy using the formula in a worksheet. They will use a simulation to gather information that they will use to complete graphs, make observations and predictions. Finally students will do word problems to complete their understanding of potential energy and kinetic energy using the formulas.

Procedures: (40- 45 min)

1. Students complete calculation of potential and kinetic energy using the formula and predict what will happen when changes are made.
2. Students use a simulation to complete a table and graph the results. This exercise will allow them to see as the mass increases the distance increases proportionally.

Experiment 1

- Students will enter the mass and velocity (this will remain constant throughout).
- Click "setup"
- Click "go/pause"
- Record distance in table.
- Repeat for additional masses in the table.
- Graph results



Experiment 2

- Students will enter the velocity and mass (this will remain constant throughtout).
- Click "setup"
- Click "go/pause"
- Record distance in table.
- Repeat for additional masses in the table.
- Graph results

Note: the simulation gives the distance and not the kinetic energy. If you are teaching highschool you can include an explanation on how the distance is related to KE. Otherwise, it is enough that the

students recognize that as the mass/velocity increases the amount of work that the car can do increases. Since we are focused on STEM we decided not to go any deeper into the science.

3. Complete the word problems on the worksheet.

   Modification: The worksheet can be completed with or without calculators. Could provide students with graphs that have intervals already established.

ELABORATE

Brief Description: Students will construct a marble roller coaster using paper towel holders and other simple materials to observe and measure how potential energy is converted into kinetic energy.

Procedures:

Estimated time options:

- Independent student project **(60-90 minutes)**.
- Small Group of 2-3 students **(45 minutes)**.

Optional challenge:

- Students and/or groups compete to get the fastest speed.

Step 1: Students will design their track on paper with the following requirements:

- One high starting point (ramp)
- One loop or curve
- One flat section at the end

Step 2: Using the formulas students will calculate potential energy of their proposed design.

Step 3: Students will build their roller coaster with the design and measurements from Step 1.

- Students can use materials available to them such as books, boxes, and/or desks to create the height they need.
- Students will use adhesives such as tape or glue to attach their components for their track.
- Students will weigh their marbles.
- Students will provide new calculations for potential energy if they had to adjust their design during the building stage.

Step 4: Test the track.

- Students will roll the marble from the top and observe its motion.
- Students will make adjustments necessary for the marble to reach the end of the track successfully.
- Students will re-calculate using the formula provided if any adjustments were made that affect their previous calculations.

Step 5: Evaluate their build

- Students will use a stopwatch/timer to calculate how long the marble takes to travel the distance of the flat section.
- Students will calculate kinetic energy.
- Students will compare their calculations for Potential and Kinetic.
- **Guiding questions:**
    - Where does the marble have the most potential energy?
    - Where is the kinetic energy the greatest?
    - What happens to the energy as the marble moves?

Step 6: Students will share their results in their evaluation.

EVALUATION

Brief Description: Students will demonstrate their roller coaster and explain the scientific processes behind their creation.

Procedures:

Presentation: (Roughly 5 minutes per student/group)

Each group or individual student will demonstrate their roller coaster to the class and explain the following using learned scientific vocabulary:

- Where potential energy is highest and why?
- Where kinetic energy is greatest and why?
- How energy is conserved or lost?

Students will be evaluated using this rubric.

Exit Ticket: (5 minutes)

Class discussion check with students asking the following questions:

- What two factors affect an object's potential energy?
- What happens to kinetic energy as potential energy decreases?
- Why doesn't the marble keep rolling forever?

REFERENCES

Vocabulary

- **Potential energy (PE)** - is the amount of energy an object has because of its relative position and height. Example: A ball held in the air has potential energy. A spring stretched against its own internal tension has potential energy. $PE = mgh$
- **Kinetic Energy (KE)** - is one way to describe the energy of motion using numbers $KE = \frac{1}{2}mv^2$
  The greater the object's mass or higher the velocity the greater the kinetic energy.
- Total energy of an object is the combination of its kinetic energy and its potential energy. If something is held at a height, the total energy comes from the potential energy. If it is dropped, when it reaches the ground, it has no potential energy. Just before impact, the total energy is only kinetic energy it gained through its fall.
- **Law of Conservation of Energy** - Energy cannot be created or destroyed as the object is dropped. Total energy is the same throughout.
- **Collision** - in collision there is a transfer of kinetic energy.

Simulation link:
https://htmlsimulations.s3.us-west-1.amazonaws.com/collision2-simulation%20-%20OpenSciEd.html

Alternate simulation link:
https://phet.colorado.edu/sims/html/energy-skate-park/latest/energy-skate-park_all.html