

Lesson Title: Rolling Rollercoasters!

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Topic: Kinetic & Potential Energy, Law of Conservation of Energy

Targeted Grade Level: 8th Grade Physical Science

Time Needed: 1 week (Block schedule)

Subject Integration: Science, Mathematics, and Engineering

Justification: In this lesson, students learn about the science topics of kinetic and potential energy, and the law of conservation of energy as energy changes forms within a system. Mathematics is integrated into this lesson as students calculate the kinetic and potential energy of objects in motion and graph the relationship between mass and the kinetic and potential energy of an object. Engineering is incorporated as students must use their knowledge of potential and kinetic energy to design and build a functioning rollercoaster and explain how energy transfers within the system of the rollercoaster. Kinetic and potential energy allow for the natural integration of mathematics, since energy can be calculated and graphed to show relationships. The engineering integration allows students to apply energy concepts in a hands-on manner.

Standards:

PA Science Standards, Assessment Anchors, and Eligible Content:

[3.2.8.B2](#) Identify situations where kinetic energy is transformed into potential energy, and vice versa.

Assessment Anchor: S8.C.2.1 Describe energy sources, transfer of energy, or conversion of energy.

- S8.C.2.1.1 Distinguish among forms of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) and sources of energy (i.e., renewable and nonrenewable energy)
- S8.C.2.1.3 Describe how one form of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) can be converted into a different form of energy.

Assessment Anchor: S8.C.3.1 Describe the effect of multiple forces on the movement, speed, or direction of an object.

- S8.C.3.1.2 Distinguish between kinetic and potential energy.

NGSS Performance Expectations

MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships 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.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
<p>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.</p> <ul style="list-style-type: none"> Develop a model to describe unobservable mechanisms. (MS-PS3-2) <p>Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.</p> <ul style="list-style-type: none"> Construct and interpret graphical displays of data to identify linear and nonlinear relationships. (MS-PS3-1) <p>Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3) 	<p>PS3.A: Definitions of Energy</p> <ul style="list-style-type: none"> Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1) A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2) <p>PS3.B: Conservation of Energy and Energy Transfer</p> <ul style="list-style-type: none"> When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5) <p>ETS1.A: Defining and Delimiting an Engineering Problem</p> <ul style="list-style-type: none"> The more precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. <i>(secondary to MS-PS3-3)</i> <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for 	<p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-1),(MS-PS3-4) <p>Systems and System Models</p> <ul style="list-style-type: none"> Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. (MS-PS3-2) <p>Energy and Matter</p> <ul style="list-style-type: none"> Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3-5) The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3)

	evaluating solutions with respect to how well they meet criteria and constraints of a problem. (<i>secondary to MS-PS3-3</i>)	
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Common Core State Standards:

PA Math Standards, Assessment Anchors, and Eligible Content:

[CC.2.2.8.B.2](#) Understand the connections between proportional relationships, lines, and linear equations.

Assessment Anchor: A1.2.1.1 Analyze and/or use patterns or relations.

- A1.2.1.1.1 Analyze a set of data for the existence of a pattern and represent the pattern algebraically and/or graphically.

Math Common Core Standards:

[CCSS.Math.Content.8.EE.B.5](#) Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater speed.

ITEEA Standards:

Standard 9. Students will develop an understanding of engineering design.

- F. Design involves a set of steps, which can be performed in different sequences and repeated as needed.
- G. Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.
- H. Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.

Measurable Student Learning Objectives:

Students will be able to...

- Explain the difference between kinetic and potential energy.
- Calculate and determine factors that influence the kinetic and potential energy of an object.
- Determine how energy transforms from one form to another to obey the law of conservation of energy.
- Design and build a model to represent the energy transformation between kinetic and potential energy in a system.

Nature of STEM:

At the start of the lesson, students will engage in the “empirical nature of science” as they observe how energy can be transformed in everyday systems, such as amusement park rides. This nature of science principle will also be addressed when students complete the Rollin’, Rollin’, Rollin’ Lab to collect data in order to calculate kinetic and potential energy. The lab also addresses the nature of math tenant of “data analysis” and “representations” as they determine and graph the relationships between the height, mass, and energy of an object. The culminating activity of the lesson requires students to build their own model of a rollercoaster to demonstrate energy transformations. This activity requires students to engage in the “inferential, imaginative, and creative nature of science” as they design a functioning rollercoaster. Students also engage in the “problem-solving” nature of mathematics and the design process of engineering as they brainstorm, design, model, test, modify, and transform their ideas into a final product to represent energy transformation.

Engaging Context/Phenomena:

To engage the students in this lesson, I show them two point-of-view perspective of rollercoasters from Hershey Park. Afterwards, we discuss differences in the rollercoasters, where the rollercoaster have the most and least energy, and thus determine how rollercoasters work.

Data Integration:

In this lesson, students are collecting and analyzing data. In the Rollin’, Rollin’, Rollin’ Lab, student measure the mass of an object, the height of ramps, and the time it takes for the object to roll down the ramp. With these measurements, students calculate the kinetic and potential energy of the object. Students then graph the mass, kinetic, and potential energy of the object to determine the relationship. Students also collect data, calculate energy, and graph the relationship between mass and energy during the culminating Rollercoaster Challenge.

Differentiation of Instruction:

Learning support students:

- Selective pairing of students
- Have text read aloud, upon request
- Have 3 (as opposed to 4) answer choices on final assessment
- Administer assessments in small group setting
- Offer extended time, as needed
- Any other modifications as directed by individual IEP

ELL Students:

- Selective pairing of students
- Offer extended time, as needed
- Abbreviated assignments
- Have text read aloud, upon request
- Repeat/Post instructions
- Guided Notes

GIEP Students:

- Adaptations and modifications will be made based upon students specially designed instruction (SDI) documents, district provided data, GIEP goals, and/or recommendations from the GIEP Team.

Specific adjustments included in the lesson procedure.

Real-life Connection:

Many of the topics in this lesson are related to theme park rides. The school district organizes a trip to Knoebels Amusement Resort for all 6th grade students, so most students have been to a theme park by my class in 8th grade. However, some students have never been to a theme park, or do not like to ride amusement park rides. In order to be make the connections relevant, we watch point-of-view perspectives of two different rollercoaster in Hershey Park. Not only does this help the student relate to the content, but it also gets them excited for the 8th grade field to Hershey Park at the end of the year!

Possible Misconceptions:

- Student do not realize that an object at rest has energy.
- Students think that energy just “disappears” instead of being transformed into different forms.

Lesson Procedure:

5E Model	5E Objectives
<p>Engage Students watch engaging videos on rollercoasters and are introduced to the concepts of kinetic and potential energy.</p>	<p>Procedure: (1/2 block)</p> <ol style="list-style-type: none"> 1. Show students two rollercoaster point-of-view videos from Hershey Park. Advise them to pay close attention to similarities and differences between the coasters. <ol style="list-style-type: none"> a. Fahrenheit (stop at 2:00) b. Storm Runner (stop at 1:30) 2. Class discussion: Utilize think-pair-share and random name generator to ensure participation <ol style="list-style-type: none"> a. What was the same/different about the two rollercoasters? b. Where do you think the rollercoasters had the most energy? c. Where do you think the rollercoasters had the least energy? d. Why did the Fahrenheit start out slowly, but the Storm Runner started with a fast projection? e. What are some things that engineers have to think about when designing and building a rollercoaster? 3. Students independently complete Kinetic & Potential Energy Edpuzzle assignment for an introduction to the terms kinetic and potential energy and continue to investigate how energy relates to rollercoasters. <p>Modifications:</p> <ul style="list-style-type: none"> • Have discussion questions posted for struggling learners and ELL students • Provide captions on the Kinetic & Potential Energy Edpuzzle assignment <p>Standards Addressed: PA Science: 3.2.8.B2 (S8.C.2.1, S8.C.3.1); NGSS: PS3.A; PS3.B</p> <p>Formative/Summative Assessments:</p> <ul style="list-style-type: none"> • Questions embedded in the Kinetic & Potential Energy Edpuzzle assignment <p>Resources:</p>

- Engagement videos: [Fahrenheit](#) and [Storm Runner](#)
- Student devices (laptops) with internet access
- [Kinetic & Potential Energy Edpuzzle](#)

Explore

Students use a simulation to observe how potential and kinetic energy transform into each other. Students are challenged to build a fun and safe virtual roller coaster.

Procedure: (1/2 block)

1. Introduce the Roller Coaster Creator activity (attached). Students complete the Review section, and then review the answers as a class.
2. Model how to use the [My Physics Lab: Roller](#) simulator in Part 1. Students must check the “show energy” option so they can observe kinetic and potential energy throughout the selected path.
 - show energy
 - show clock
 - pan-zoom
3. Students work with a partner to complete the Roller Coaster Creator activity. During this activity students use a simulation ([My Physics Lab: Roller](#)) to observe the transformation of kinetic energy into potential energy and determine where moving objects have the greatest kinetic and potential energy. Then students are challenged to use a simulator ([Amusement Park Physics](#)) to create a fun and safe rollercoaster.
4. Students independently complete [Kinetic & Potential Energy Quizizz](#) to assess current understanding of kinetic and potential energy

Modifications:

- Guided introduction to Part 1 of the Roller Coaster Creator activity completing 2-3 examples together as a class
- Modify Quizizz to allow for a longer time to answer questions

Standards Addressed: PA Science: [3.2.8.B2](#) (S8.C.2.1, S8.C.3.1); NGSS: PS3.A; PS3.B

Formative/Summative Assessments:

- Kinetic & Potential Energy Quizizz

Resources:

- Student devices (laptops) with internet access
- Roller Coaster Creator Worksheet (attached) (1 per student)
 - [My Physics Lab: Roller](#)
 - [Amusement Park Physics](#)
- [Kinetic & Potential Energy Quizizz](#)

Explain

Students read articles, participate in a class presentation, write examples, and draw diagrams in their science notebook for an understanding of kinetic and potential energy.

Procedure: (1 block)

1. Present the [Kinetic and Potential Energy Nearpod](#) to the class
 - Students write examples and draw diagrams in their science notebook
 - Learning support and ELL students complete Kinetic and Potential Energy Guided Notes (attached)
 - Students complete the embedded checks for understanding and activities in the Nearpod presentation
2. Introduce KE and PE Calculations Practice (attached). Complete number one as an example to model how to highlight known information, write the proper formula, substitute values (in the correct order), and calculate an answer with a label.
3. Students work with a partner to complete KE and PE Calculations Practice to identify if an object has potential or kinetic energy in each situation and calculate the amount of the energy it possess.
4. Students independently read "[Energy Screams](#)" article on ReadWorks and complete the comprehension questions about kinetic and potential energy.

Modifications:

- Guided Kinetic and Potential Energy Notes for lower-level learners
- Bolded text and formula frames on the KE and PE Calculations Practice Worksheet
- Audio recording of "Energy Screams" article available

Standards Addressed: PA Science: [3.2.8.B2](#) (S8.C.2.1, S8.C.3.1); NGSS: PS3.A; PS3.B

Formative/Summative Assessments:

- Embedded formative assessments in Kinetic and Potential Energy Nearpod
- KE and PE Calculations Practice Worksheet
- "Energy Screams" ReadWorks comprehension questions

Resources:

- Student devices (laptops) with internet access
- [Kinetic and Potential Energy Nearpod](#) Presentation
- Guided Kinetic and Potential Energy Notes (attached) (1 per identified students)
- Colored Pencils
- Calculators (1 per student)
- KE and PE calculations Practice Worksheet (attached) (1 per student)
- "[Energy Screams](#)" ReadWorks article

Elaborate

Students complete a lab to calculate the kinetic and potential energy of an object, and graph the mass vs. kinetic and potential energy to determine the relationship between these variables.

Procedure: (1 block)

1. Introduce Rollin', Rollin', Rollin' Lab (attached). Read over the materials and procedures as a class.
2. Demonstrate how to complete one trial measuring and recording data when noted in the procedure.
3. Students work in groups to complete the Rollin', Rollin', Rollin' Lab. During this lab, students measure the mass of three balls, the height of a ramp, and the time it takes for the ball to roll down the ramp. With this information, students calculate the velocity of the ball, and its kinetic and potential energy.
4. Once students have calculated the kinetic and potential energy, groups share their data with the class and then graph the relationship between mass and kinetic/potential energy.
5. Model how to complete the graph using two different colors to represent kinetic or potential energy. Students must complete the graph and conclusion questions for homework if not finished by the end of class.

Modifications:

- Label the balls with their mass (to save time)
- Formula frames for velocity, kinetic energy, and potential energy calculations
- Guided graphing to set up the x-axis label, y-axis label, title, key, and scale together as a class

Standards Addressed: PA Science: [3.2.8.B2](#) (S8.C.2.1, S8.C.3.1); NGSS: MS-PS3-1; MS-PS3-2; PS3.A; PS3.B; PA Math: [CC.2.2.8.B.2](#) (A1.2.1.1.1); CCSS.Math.8.EE.B.5

Formative/Summative Assessments:

- Rollin', Rollin', Rollin' Lab conclusion questions

Resources:

- Rollin', Rollin', Rollin' Lab Directions (attached) (per group)
- Rollin', Rollin', Rollin' Lab Worksheet (attached) (1 per student)
- Calculators (1 per student)
- Lab Materials (per group):
 - Variety of sports balls (kickball, basketball, soccer ball, volleyball, dodgeball, tennis ball, whiffle ball, golf ball, ping pong ball, bouncy ball, marbles, etc.) (3 per group)
 - 1 meter long Ramp
 - 5 textbooks

- Meter stick
- Triple Beam Balance
- Stopwatch

Procedure: (2 blocks)

- Show students [Engineering Thrills](#) video to circle back to the Engagement video and relate to their upcoming challenge.
- Introduce the Rollercoaster Challenge (attached). Read over the challenge, materials, and rollercoaster scoring rubric as a class.
- Guide students through the “Identify the Problem” section with class discussion.
- Students work in groups to complete the Rollercoaster Challenge to design a functioning foam rollercoaster.
 - Groups first research successful rollercoasters
 - Consider possible constraints to rollercoaster design
 - Determine science knowledge that will be helpful to consider
 - Design their rollercoaster for teacher-approval
- As students brainstorm and design, monitor to prompt and question students to relate their designs to their science content knowledge.
- Approve student designs if there are at least two special features and all parts of the design are labeled. Ensure that the first hill is the tallest in their design.
- Students continue to work in groups to build a functioning foam rollercoaster.
 - Build the rollercoaster using only the provided materials
 - Test and redesign the rollercoaster for safety and speed
- When all groups have built their final track, each group presents their rollercoaster to the class and tests the three marbles. Students must time each marble run in order to be able to calculate and graph the kinetic and potential energy of each marble.
- Score each rollercoaster using the scoring rubric for creativity and performance.
- Students complete the self-reflection when finished with the challenge.

Modifications:

- Guided introduction to review the science knowledge necessary to be successful
- Example rollercoaster tracks posted for inspiration
- Formula frames for velocity, kinetic energy, and potential energy calculations
- Guided graphing to set up the x-axis label, y-axis label, title, key, and scale together as a class

Evaluate

Students use their knowledge of kinetic and potential energy to design and build a successful rollercoaster of their own and calculate the kinetic and potential energy of the marble as it completes the rollercoaster track.

Standards Addressed: PA Science: [3.2.8.B2](#) (S8.C.2.1, S8.C.3.1); NGSS: MS-PS3-1; MS-PS3-2; PS3.A; PS3.B; PA Math: [CC.2.2.8.B.2](#) (A1.2.1.1.1); CCSS.Math.8.EE.B.5; NGSS:ETS1.A; ETS1.B; ITEEA Standard 9

Formative/Summative Assessments:

- Summative: Successful completion of the Rollercoaster Challenge.

Resources:

- Engagement video: [Engineering Thrills](#)
- Teach Engineering: [Physics of Roller Coasters](#) & [Building a Roller Coaster](#) (Resource found via Endeavor)
- Rollercoaster Challenge Directions (attached) (per group)
- Rollercoaster Challenge Worksheet (attached) (1 per student)
- Calculators (1 per student)
- Rollercoaster Challenge Materials (per group):
 - 2 meter long foam tube
 - Glass Marble
 - Wooden Marble
 - Steel Marble
 - Paper cup
 - Masking tape
 - Markers, crayons, or colored pencils
 - 1 sheet of blank paper
 - Stopwatch
 - Meter stick
 - Triple Beam Balance

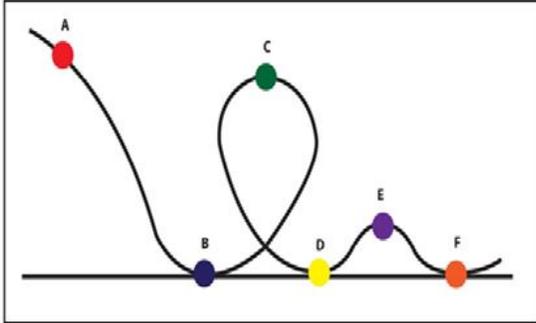
Teacher Background:

Teachers need an understanding of energy, types of energy, and energy transformations (see links below). Teachers also need to know how to navigate and utilize online resources such as Edpuzzle, Nearpod, Quizizz, and ReadWorks.

- [What is Energy?](#)
- [Kinetic and Potential Energy](#)
- Teach Engineering: [Physics of Roller Coasters](#) & [Building a Roller Coaster](#) (Resource found via Endeavor)

Roller Coaster Creator

Review: Use the picture below to answer the following questions.



1. In which location(s) does the rollercoaster have 100% potential energy?
2. In which location(s) does the rollercoaster have 100% kinetic energy?
3. Describe the potential and kinetic energy at location E.
4. What do you think is the percent of potential and kinetic energy at location C?

Part 1: Go to: <https://www.myphysicslab.com/roller/roller-single-en.html>

Use the drop-down menu to select the path of the roller coaster. Sketch the path, and label where the potential and kinetic energy are at their maximum.

Path	Path Sketch & Label	Path	Path Sketch & Label
Hump		Lemniscate	
Loop		Cardioid	
Circle		Spiral	
Oval		Flat	

Part 2: Go to: <https://www.learner.org/series/interactive-amusement-park-physics/>

Read the introduction information. Click on The Roller Coaster to answer the questions below:

1. A roller coaster does not have any engine. What drives the roller coaster?
2. What is the difference between a wooden and steel coaster?

Click on Ride Safety on the roller coaster picture at the bottom to answer the following questions:



1. What is the statistic of death on a roller coaster?
2. What percentage of visitor go to the emergency room for injuries on roller coasters?
3. What is the major cause of death or injury on a roller coaster? How does the amusement park prevent these incidents?

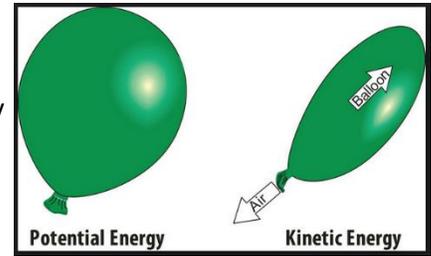
Click on Design a Roller Coaster to build a rollercoaster, sketch your design, and determine if it has passed the safety rating and fun rating. Click on the first part of the rollercoaster to rebuild at least four more times. Build until successful.

Trial	Design Sketch	Safety Rating Circle One:	Fun Rating Circle One:	Why do think your design was not successful?
1		<input type="radio"/>  <input type="radio"/> 	<input type="radio"/>  <input type="radio"/> 	
2		<input type="radio"/>  <input type="radio"/> 	<input type="radio"/>  <input type="radio"/> 	
3		<input type="radio"/>  <input type="radio"/> 	<input type="radio"/>  <input type="radio"/> 	
4		<input type="radio"/>  <input type="radio"/> 	<input type="radio"/>  <input type="radio"/> 	
5		<input type="radio"/>  <input type="radio"/> 	<input type="radio"/>  <input type="radio"/> 	

Unit 7: Kinetic and Potential Energy Notes

What is Energy?

- **Energy** – the ability to do _____
- The ability to move or cause change in _____
- Two types of energy: _____ energy and _____ energy

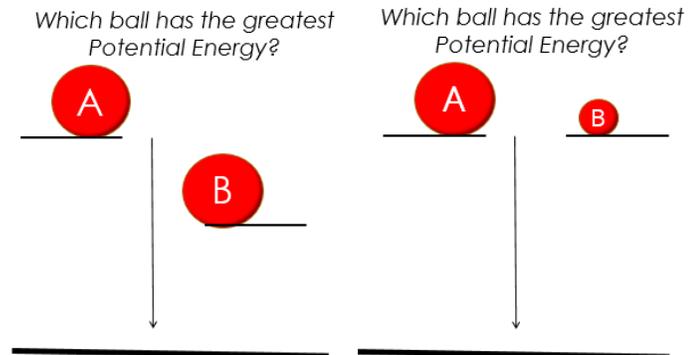


What is Potential Energy?

- **Potential Energy** – stored energy in an object due to _____
- Found in _____ objects
- Energy ready to be used, but not being used
- Can be transformed into other types of energy
- SI unit is the _____ (J)
- Two types of potential energy: Gravitational and Elastic

What Determines Gravitational Potential Energy?

- Determined by _____ and _____
- Higher objects → _____ potential energy
- _____ mass → greater potential energy



What is Elastic Potential Energy?

- **Elastic Potential Energy** – stored in elastic materials as a result of their stretching or compressing
- Amount of energy is related to the _____ applied
- Objects with elastic potential energy: _____, bungee cords, trampolines, _____, etc.
- _____ stretch → greater potential energy

Calculating Potential Energy

- $PE = m \times g \times h$ OR $PE = w \times h$
- $m = \text{mass in } \underline{\hspace{2cm}}$ $w = \text{weight in } \underline{\hspace{2cm}}$
- $g = \text{gravitational field} = 9.8 \text{ N/kg}$
- $h = \text{height in } \underline{\hspace{2cm}}$

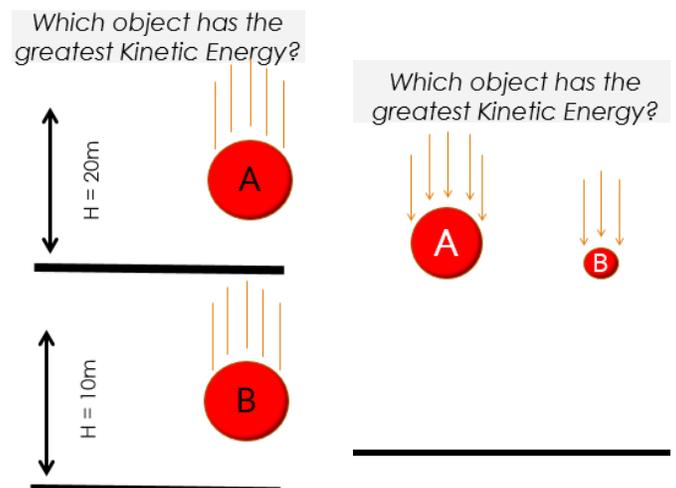
A 1 kg bag of apples is sitting on a table 3 meters high. What is the potential energy of the bag of apples?

What is Kinetic Energy?

- **Kinetic Energy** – energy of _____
- Found in _____ objects
- Formed or caused by motion
- Can be transformed into other types of energy
- SI unit is _____ (J)

What Determines Kinetic Energy?

- Determined by _____/velocity and _____
- _____ object → greater kinetic energy
- Greater mass → _____ kinetic energy



Calculating Kinetic Energy

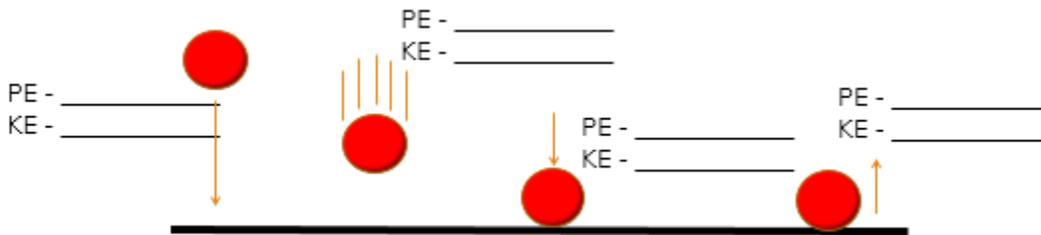
- $KE = \frac{1}{2} \times m \times v^2$
- $m = \text{mass in } \underline{\hspace{2cm}}$
- $v = \text{velocity in m/s}$

A 1816 kg car (2 tons) is travelling at 26.8 m/s (60 mph). What is its kinetic energy?

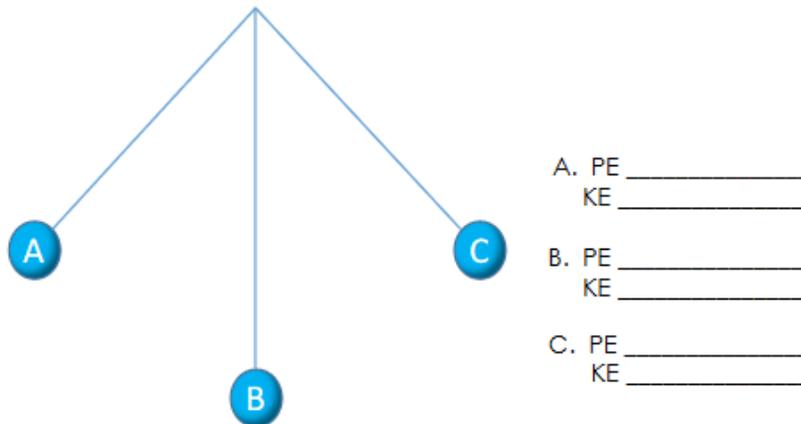
Law of Conservation of Energy

- **Law of conservation of energy** – states that energy cannot be _____ or _____, however energy can change _____
- The potential and kinetic energy of an object changes as it _____

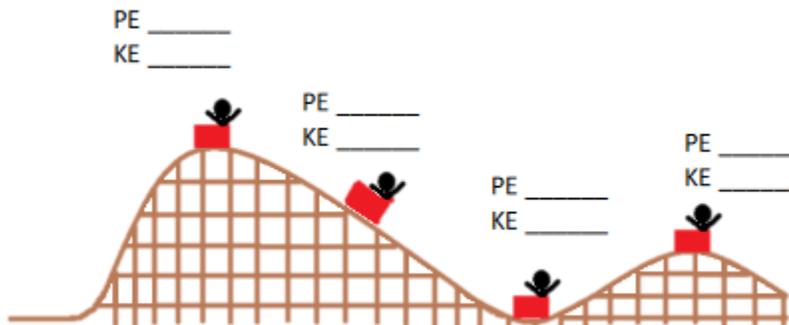
Bouncing Ball:



Pendulum:



Rollercoaster:



KE and PE Calculation Practice

Determine whether the objects have kinetic (K) or potential (P) energy on the line. Calculate the kinetic or potential energy of each object using the correct formula. **Each problem requires three steps of work: formula, substitution, answer.**

Remember units!

$$KE = \frac{1}{2} \times m \times v^2$$

$$PE = m \times g \times h \quad \text{OR} \quad PE = w \times h$$

1. You serve a tennis ball with a mass of 0.9 kg . The ball leaves your hand with a speed of 73 m/s . The ball has _____ energy.

Known Info:

Formula:

Substitution:

Answer:

$$m =$$

$$v =$$

2. A dog is sitting at the top of a hill that is 21 m high. The dog weighs 12 N . The dog has _____ energy.

3. A car is traveling with a velocity of 46 m/s and has a mass of 1200 kg . The car has _____ energy.

4. A rock is sitting on a platform 20 m high. It weighs 65 N . The rock has _____ energy.

5. There is a 130 kg bell at the top of a tower that is 50 m high. The bell has _____ energy.

6. A 96 kg Flume boat is at the top of a 72 m hill. The Flume boat (at this moment) has _____ energy.

7. What is the kinetic energy of a 6 kilogram ball that is rolling at $4 \text{ meters per second}$?

Rollin' Rollin' Rollin'

In this lab, we will explore the effect of the height of a ramp and the mass of an object on the potential and kinetic energy.

Materials:

- 3 Balls with different masses
- Ramp (a piece of plywood)
- 5 Textbooks
- Meter Stick
- Triple Beam Balance
- Stopwatch
- Calculator

Procedure:

1. Write which balls you selected in the table.
2. Find the mass of each ball using the triple beam balance (in grams). Using **KHD_bDCM**, convert the mass from grams to **kilograms**. Record the mass in the table.
3. Place two books under the end of the board to make a ramp. Place another book at the end of the ramp to stop the ball. See picture below:



4. Measure the height of the ramp in **meters** and record it.
5. Place one of the balls on the starting line.
6. Release the ball and start the stopwatch.
7. When the ball hits the book, stop the stopwatch.
8. Record the distance (in **meters**) that the ball traveled and the time in **seconds**.
9. Repeat steps 5 – 8 with each ball.
10. Place two more books under the end of the plywood. Record the new height of the ramp, in **meters**.
11. Repeat steps 4-8 with each ball at the new height.
12. Calculate the potential and kinetic energy of the balls. Remember to show all work and include units. Round to the nearest tenth.
13. Record the mass, kinetic energy, and potential energy of each ball on the board.
14. Graph the mass vs kinetic and potential energy using the class data.

Necessary Formulas:

$PE = m \times g \times h$	$m = \text{mass (kg)}$ $g = 9.8 \text{ m/s}^2$ $h = \text{height (m)}$
$KE = \frac{1}{2} \times m \times v^2$	$m = \text{mass (kg)}$ $v = \text{velocity (m/s)}$
$v = \frac{d}{t}$	$d = \text{distance (m)}$ $t = \text{time (s)}$

Rollin' Rollin' Rollin'

Hypothesis: Fill in the blanks with increase, decrease, or stay the same. (1 pt)

If the height of a ramp increases, then the potential and kinetic energy will _____. If the mass of an object increases, then the potential and kinetic energy will _____.

Data Collection: 1st Ramp Height (6 pts)

Height of ramp (h) = _____

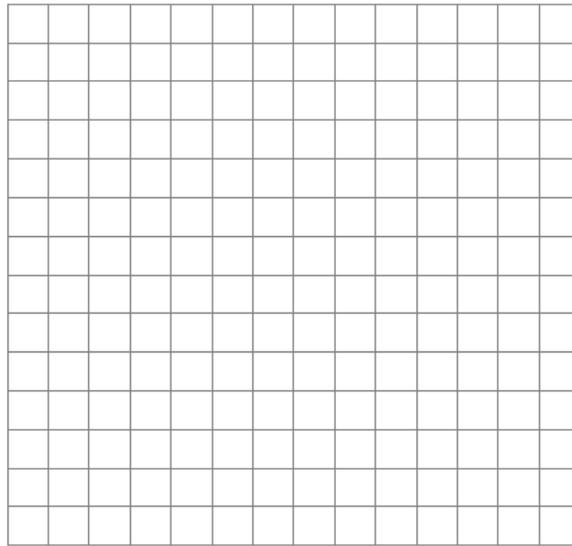
	Mass (kg)	Distance (m)	Time (s)	Velocity (m/s) $v = \frac{d}{t}$	Potential Energy (J) $PE = m \times g \times h$	Kinetic Energy (J) $KE = \frac{1}{2} \times m \times v^2$
Ball 1:						
Ball 2:						
Ball 3:						

Data Collection: 2nd Ramp Height (6 pts)

Height of ramp (h) = _____

	Mass (kg)	Distance (m)	Time (s)	Velocity (m/s) $v = \frac{d}{t}$	Potential Energy (J) $PE = m \times g \times h$	Kinetic Energy (J) $KE = \frac{1}{2} \times m \times v^2$
Ball 1:						
Ball 2:						
Ball 3:						

Graph: Use the class data to graph the relationship between mass and energy. The graph should have one color to represent kinetic energy and one color to represent potential energy. Remember to create a key and include all **SULTAN** elements. (7 pts)



Conclusion Questions: Answer each question by restating the question and using complete sentences. (7 pts)

1) When did each ball have potential energy? Kinetic energy?

2) Describe the relationship represented on the graph above.

3) As the mass of the ball increased, what happened to the kinetic energy of the ball? Support your claim with data.

4) As the height of the ramp changed, what happened to the kinetic energy of the ball? Support your claim with data.

5) When a car is going downhill, the driver must apply more pressure on the brakes, than if the car was on level ground. Why?

6) Why is a four-person bobsled harder to stop than a three-person bobsled?

7) As potential energy increases, what happens to the kinetic energy?

Rollercoaster Challenge

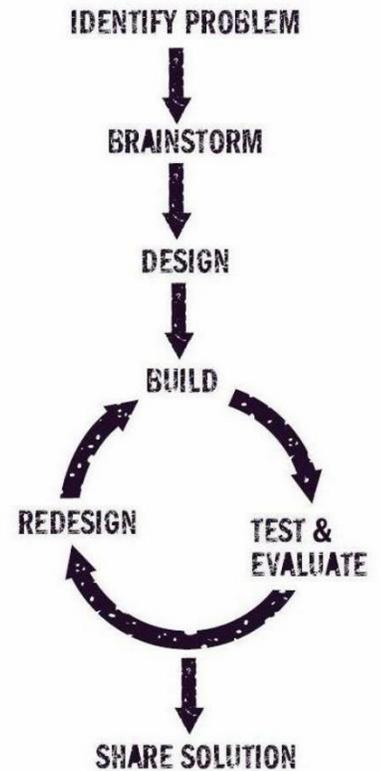
Challenge: Design and build a model rollercoaster that is thrilling, yet safe for the riders! Your rollercoasters will be judged on creativity and performance.

Marbles represent riders in your rollercoaster. The glass marble models a normal car, the wooden marble represents an empty car, and the steel marble represents a full car. You earn points for each type of marble that successfully completes your track and lands safely in the cup.

Materials:

- 2-meter (6 foot) long foam tube
- glass marble
- wooden marble
- steel marble
- paper or plastic cup
- roll of masking tape
- set of markers, crayons or pencils
- blank sheet of paper
- stopwatch
- meter stick
- calculator
- triple beam balance

THE DESIGN PROCESS



Rollercoaster Scoring Rubric:

Creativity Points:

Points are awarded for each of the following items included in a group's roller coaster.

Every 50 cm of height	1 point
90° turn	1 point
180° turn	2 points
270° turn	3 points
Loop	3 points
Corkscrew	4 points

Performance Points:

Points are awarded for each type of marble that successfully completes the roller coaster and lands in the paper cup.



Rollercoaster Challenge: Student Lab

Identify the Problem: *(10 points)*

Research: Questions to ponder.

1. What makes a rollercoaster fun to ride?
2. What do rollercoasters have in common? Check out some of the [best rollercoasters](#) across the country!
3. What are some constraints the engineers would have to consider when designing a rollercoaster?

Science Knowledge:

4. What is potential and kinetic energy?
5. What is the law of conservation of energy?
6. How do energy (kinetic and potential) relate to a rollercoaster?
7. Where is the most potential energy found in a rollercoaster?
8. Where is the most kinetic energy found in a rollercoaster?
9. How do gravity and friction relate to a rollercoaster?
10. Summarize what implications these science principles have on your rollercoaster design.

Brainstorm & Design: *(5 points)*

Draw an initial sketch. Remember to include loops, corkscrews, hills, and spirals. You will gain points for each feature if the marble travels on the path. Label all parts. Be sure to brainstorm a name and create a sign advertising your rollercoaster to your classmates.

Teacher Check: _____

Build: Create it! Start building the rollercoaster.

Test & Evaluate: *(5 points)*

What is Working?	What Needs to be Improved?

Solution: (10 points)

Draw a sketch of your **final** rollercoaster design.

Height (cm): _____

of Loops: _____

of Corkscrews: _____

of Turns: _____

Glass Marble Mass: _____

Wooden Marble Mass: _____

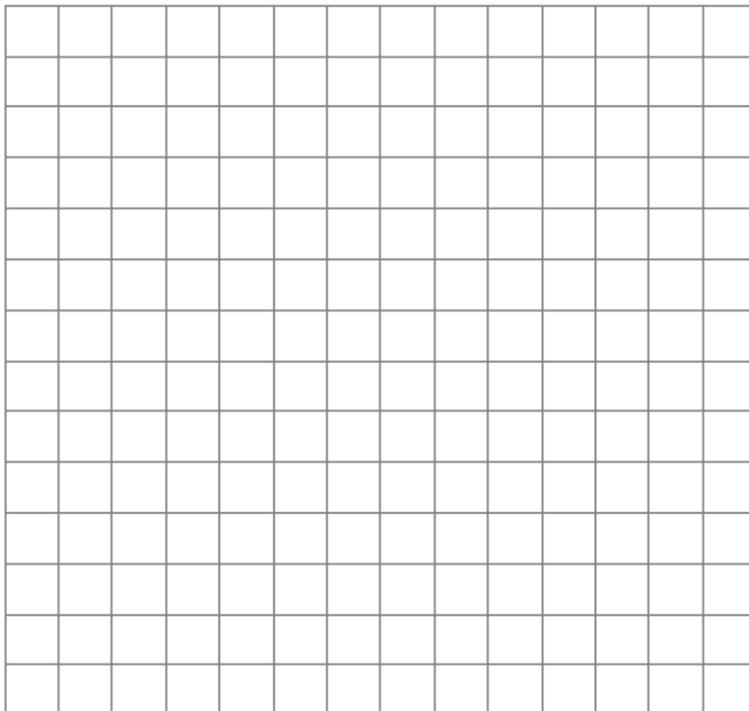
Steel Marble Mass: _____

- Label a point (A) on your rollercoaster where the cars accelerate.
- Label a point (B) on your rollercoaster where the cars decelerate.
- Label a point (C) on your rollercoaster where the cars have the greatest potential energy.
- Label a point (D) on your rollercoaster where the cars have the greatest kinetic energy.
- Label a point (E) on your rollercoaster where potential energy is changing into kinetic energy.
- Label a point (F) on your rollercoaster where kinetic energy is changing into potential energy

Kinetic and Potential Energy: Calculate the maximum kinetic and maximum potential energy of each of the marbles. Show all work. (6 points)

Glass	Wooden	Steel
KE = _____ PE = _____	KE = _____ PE = _____	KE = _____ PE = _____

Kinetic and Potential Energy: Graph the relationship between the marble mass and energy. The graph should have one color to represent kinetic energy and one color to represent potential energy. Remember to create a key and include all **SULTAN** elements. (8 points)



Describe the relationship between marble mass and energy as evident from the graph.

Self-Reflection:

1. What did you learn from this experience? Would you want to do this again?
2. How well did you work with your group?
3. What ere some creative risks that you took?
4. Why is it important to brainstorm with others?