Racing Roller Coasters

Sherry Barnett

A STEM Unit intended for Grade Levels 7th – 9th

July 28, 2017

Introduction:

The racing roller coasters unit will challenge students to think about the concept of systems. They will be asked to use the engineering and design processes and will be challenged to create a working roller coaster. Students will collaborate to create designs and turn them into a paper roller coaster. They will have to work as a team to integrate the best ideas and figure out how to make the twists and turns needed for an exciting ride. As students create their coasters they will be learning about all the systems required for a roller coaster to work properly. Students will have to use concepts of energy and forces to make changes to their coasters to ensure they can hit top speeds and have a long lasting ride. Not only will they create an exciting roller coaster they will also use what they have learned about forces and energy to explain the physics behind the exciting rides.

Rationale:

During the racing roller coasters unit students will be working on different skills that are important for them to learn and use. Students will spend time each day working with their team collaboratively to design and build a functioning roller coaster. They will have to utilize communication skills and leadership skills in order to complete the project effectively in the time allotted. Students will have opportunities to work on different roles during the lessons allowing them to learn how to work with a team. Working and communicating effectively with a team is an important skill for students to start working on before they are trying to use these skills in the workforce. This skill is particularly important for gifted students because some of them have the "I'd rather do it myself" attitude. This project causes students to depend on their group in order to be successful. Another skill students will be working on during the unit is persevering to solve a problem. It is important for students to see that they have the ability to work through a problem that is challenging to them. This is an important skill because we want students to have the confidence to work on problems that appear to be challenging to them. The largest amount of learning will occur when students feel challenged. Gifted students who have not been challenged often may have a tendency to shut down. This is a supportive process that will help them be successful and challenged. Lastly, students will be focusing on being able to explain and justify their reasoning for decisions. During this lesson students will be required to think about what changes they would make to improve their designs and how those changes will affect how it functions. Students will have to be able to clearly explain their reasoning to their teams and justify their reasoning when needed. This process will help students practice articulately their ideas and thoughts to other people. Many students have great ideas but they need to be able to explain these thoughts to others.

The content integrated throughout this unit is important for students to learn and understand. Students will be working with concepts related to types of energy, energy conservation, velocity

and the computations to go with each area. Students will learn about the relationship between potential and kinetic energy as well as how those types of energy can affect velocity. They will make estimates and change to see how increasing height can impact the amount of energy in the system as a whole. This leads students to learning about the importance of looking at the bigger picture before making changes. They will see that even a minor change can make a major impact on the entire system and how it functions. Students will learn the importance of accurate calculations in order to have a successful outcome.

This unit incorporates concepts that are important for students to learn. Students will be discussing systems and more specifically how systems manipulate movement. Systems is a broad concept that can be connected to many other content and curriculum areas. Students will be able to make connections between the concepts in the roller coaster unit and the concept in other content areas. Students need to have an understanding of what a system is. Through many discussion questions students will learn how to define a system and then discuss how we can use systems to manipulate movement. Not only do systems manipulate movement in an energy system like roller coaster but this occurs in other areas such as the body systems. Students should be able to make these connections in order to have a strong understanding of the concept. Students need to understand different types of systems that we have in our lives and how they interact.

Differentiation for Gifted Learners:

This unit incorporates many different aspects of differentiation that are appropriate for gifted learners. It encompasses aspects of differentiation on many levels including in content, processes, product and learning environment. The unit allows flexibility for further differentiation to include creativity, complexity, challenge, depth and acceleration. These lessons can be modified to meet the needs of different groups of gifted students. The pre-lesson questions in lesson one allow the teacher an opportunity to learn students current knowledge of the material which gives the opportunity to adjust as needed for different groups of students.

Content:

The content of this unit can be differentiated to meet the needs of gifted learners. The content is above grade level for the intended audience of the unit which allows for many methods of differentiation. Depending on students prior knowledge the content can be adjusted to meet the needs of all learners. The depth and complexity can be adjusted based on how students are introduced to the calculations. Students can be given the formulas or challenged further by discovering formulas. The students will also need to have the ability to manipulate formulas which is a complex skill .

Processes:

This unit offers multiple instructional strategies, which offer differentiation in the processes, including Problem Based Learning, Visual Thinking Strategies, Creative Problem Solving and Taba. Along with the different instructional strategies each lesson has numerous higher-level questions that challenge students to think in depth about the content. The questions allow for various level of complexity within in the content. Lastly, the groups are set up to have different roles for students to be assigned daily. This allows for each student to have a different experience within each role. The roles can be teacher assigned or student directed. This processes will challenge gifted learners to use their critical thinking skills and problem solving abilities.

Product:

The culminating product of this project is an originally designed roller coaster made out of paper. To adjust the complexity and challenge of the product you could allow students to use different materials. This unit was written to only allow paper, tape and a limited number of paper towel rolls. Giving different materials would change the challenge of creating the product. Each roller coaster will be unique to the group making it allowing for many differences in product designs. Students also have options on how they would like to present their finding of the physics behind their roller coasters. Additionally if more time is allotted students could add product pieces such as having a theme for their coaster, advertisements, or calculating the cost to build their coaster. Each additional piece would add to the complexity of the product being created.

Learning Environment:

The learning environment during the unit has many changes. It is important for gifted learners to vary the interactions they are having. This unit allows for individual think time and questioning, partner work and group work. During group work roles are assigned allowing learners to focus on different aspects of the project. During lesson plan 4 students are given a problem and are to use their skills to and prior knowledge to solve. This sets students up for independent learning that is challenging and supported. Gifted learners need to be challenged but also have a strong support system to ensure they are successful.

Population for whom the unit is intended:

Racing Roller Coasters was written for rising 7^{th} – 9^{th} graders as a part of a summer program offered by Rockingham County Schools. The summer program is free and sign up is offered to all AIG students in the county on a first come first serve basis. The classroom size is limited to 16 students in the summer program. Students in the program come from a variety of backgrounds and bring varying experiences to the program. The classrooms have a range of students.

Rockingham County has a range of socioeconomic backgrounds which was displayed in students who attended. The camp was run during the day and students had to be picked up which may have caused some children with working parents to be unable to attend. The classroom consisted of 8 white students, 2 African American Students and 1 Hispanic students. According to the Annual Report done by Rockingham County Schools (https://www.rock.k12. nc.us/annualreport) it has the following ethnic breakdown: 63% white, 20% black, and 12 % Hispanic, and 5 % other. The class had a similar ethnic breakdown to the county as a whole. The class was a majority male class with 7 boys and 4 girls. Consideration for students of all socioeconomic backgrounds, ethnicities and genders were made when writing the unit lessons.

Students in the course seemed to all have an interest in science, math and engineering. Many of them signed up for the course because of their interests in the fields. The students came with strong background knowledge of types of energy and energy conservation. They were more challenged by the math concepts and the relationship between the types of energy. Students participating in this unit need to have the ability to compromise and work with a team. They need to do well with student lead and driven learning.

Goals and Outcomes:

The following goals were established for the unit in areas of content, processes and concept. Each goal has multiple outcomes that will be assessed to see if full understanding of the goal was met.

Content Goals and Outcomes:

Goal 1: Students will understand types of energy, conservation of energy and energy transfer.

Students will be able to…

- **A.** Distinguish between types of energy and determine which type of energy is being used during (Kinetic, Potential or both).
- **B.** Analyze a situation to determine how energy is being transferred.
- **C.** Describe how energy is changing within a system
- **D.** Explain that energy can change but is never created or destroyed within a system.
- **E.** Analyze the affects friction can have on kinetic and potential energy.
- **F.** Calculate potential and kinetic energy.
- **G.** Estimate changes in energy based on changing other factors in a system.

Process Goals and Outcomes:

Goal 3: To develop the ability to make sense of problems and preserver in solving them

Goal 4: To develop the ability to construct viable arguments and critique the reasoning of others.

Students will be able to…

- **A.** Articulate ideas clearly and thoroughly
- **B.** Justify their thinking and reasoning with data and facts
- **C.** Identify key information and features of a problem
- **D.** Create a plan for solving a problem and make changes if needed
- **E.** Use critical thinking to solve problems with groups
- **F.** Formulate ideas and incorporate others opinions

Concept Goals and Outcomes:

Goal 5: To understand the concept of systems.

Students will be able to…

- **A.** Identify systems that are a part of roller coaster
- **B.** Predict the outcomes when changes are made to various systems
- **C.** Analyze the impact of changing various systems
- **D.** Explain how smaller systems are a part of a whole system
- **E.** Analyze how systems manipulate movement
- **F.** Relate what they learned about systems to other content areas

Assessment Plan

This unit includes a wide range of assessment types. Varying the types of assessments allows students the opportunity to show their learning in multiple ways. In includes a summative assessment as well as copious opportunities for formative assessment.

Formative Assessment:

Formative assessment is ongoing throughout the unit. In order to be sure that students are gaining knowledge form day to day formative assessment must be integrated. Formative assessment can take place at any point during a lesson. Formative assessment in this unit would occur during discussion, questioning and conversations with groups. For example during Unit Lesson 1 (Taba) formative assessment was used while students were creating groupings and

sharing their groupings. This allows the teacher to see if students understand the concepts they read about in the article. When students shared their groups asking them to explain their reasoning allows the teacher to see if they fully understand the concepts. These opportunities occur in each of the lessons in the unit. Formative assessment is integrated in many other aspects of the unit including opening questions in the morning and closure activities. Students are often asked to reflect on their learning form the day. Exit tickets were used in order to guide any changes that may need to occur in the next day's lesson based on understanding from the previous lesson. Daily student reflections on learning allow for check-ins to ensure that learning is occurring and students are moving towards achieving the learning goals. In Unit lesson 3 students are given a diagram of a roller coaster and asked to predict when the roller coaster has its maximum potential energy, kinetic energy and velocity. Through discussions with students and explanations of their thinking we can assesses what their current knowledge is. The predictions should guide the discussion to address misconceptions and lead to the learning goals. In unit lesson 4 students are working on a problem based learning model. The problem will allow for us to assess student understanding of how to calculate different types of energy.

Summative Assessment:

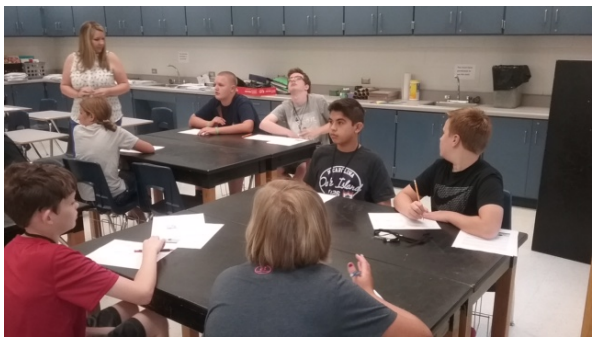
Throughout the week students will be working on the summative assessment project (task). For the final task students will be building a roller coaster out of paper. They will be competing to create a roller coaster ride that has the top speed, longest ride and has exciting twists and turns. During the week they will learn about systems that are a part of a roller coaster and look at how those systems manipulate movement. There final assessment will include looking at their original roller coaster design and final design. Students will have to explain changes they made and why they made changes to the design. How did these changes impact the movement and which systems did they change. Students will also be asked to explain the physics behind their coaster. They will do calculations to find the energy and velocity (top speed) of their roller coaster. Each team has the flexibility to decide how they want to present their findings and how they design their roller coaster. Students presenting their findings and discussing their design changes will allow for assessment of all the learning goals for the unit.

Example Assessment Rubric:

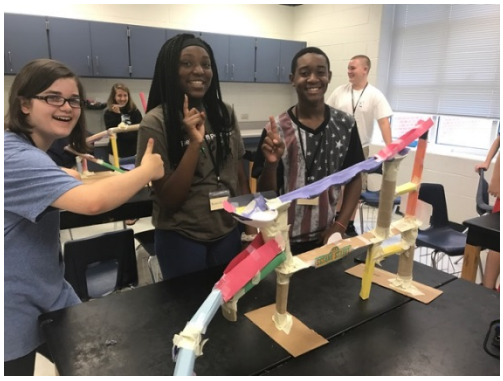
This final task of this unit has multiple parts students were required to design/ re-design and build a roller coaster as well as explain the physics. This rubric has been adjusted to meet requirements that would be used in a classroom when a longer amount of time is available to complete the project.

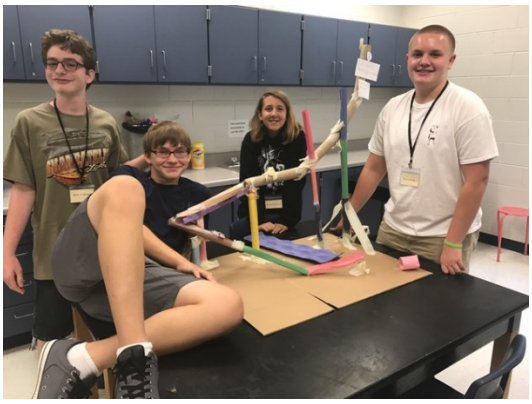
Performance Indicator	Distinguished (3)	Accomplished (2)	Developing (1)	Total
Roller Coaster Time (Weight x 3)	Roller Coasters average time was longer than 20 seconds	Roller Coasters average time was between 15 and 20 seconds	Roller Coasters average time was less than 15 seconds	
Twist & Turns (Weight x 1)	The Roller coaster included at least 3 loops, funnels, jumps or other excitement factors	The Roller coaster included at least 2 loops, funnels, jumps or other excitement factors	The Roller coaster included at least 1 loops, funnels, jumps or other excitement factors	
Design Process (Weight x 1)	All designs were included in the final project and completed as changes were made	Some designs were included in the final project and completed as changes were made	Few designs were included in the final project and completed as changes were made	
Design Rationale (Weight x 2)	Explanations of changes made during the design processes were clearly presented with articulate justification.	Explanations of changes made during the design processes were presented and had some justification	Explanations of changes were presented but lacked justification.	
Calculations (Weight x 2)	Calculations were presented and accurate. The presentation included the work	Calculations were presented and most were accurate. Work was included	Calculations were presented but were not accurate or lacked work	
Team Work	Group work efficiently and used time wisely. All group members participated	The group work efficiently some of the time. Most group members participated	The group did not use time to their advantage or work efficiently. A few group members participated.	

Student Work and Final Designs



Above: Students working on the original designs after looking at the materials offered. Each student created their own design then teams decided on which was the best design to use moving forward. All designs were adjusted many times before finalizing their roller coasters.





Top Left: *Stairway to Heaven*: This roller coaster was the longest lasting and had the most twist and turns.

Top Right: *Elmo's World:* This design was voted as the most stable structure.

Bottom: *The SpongeBob:* This roller coaster hit the top speed!

Students in these sections gave verbal presentations to explain the physics of their roller coaster.

Lesson Plans:

TEACHER NAME			Lesson #
Sherry Barnett			1
MODEL	**CONTENT AREA**	**GRADE LEVEL**	
Taba	**STEM**	**7-9**	
CONCEPTUAL LENS		**LESSON TOPIC**	
Systems		**Roller Coasters**	

LEARNING OBJECTIVES *(from State/Local Curriculum)*

PSc.1.1: Understand motion in terms of speed, velocity, acceleration, and momentum.

PSc.1.2: Understand the relationship between forces and motion**.**

PSc.3.1: Understand types of energy, conservation of energy and energy transfer.

CCSS.MATH.PRACTICE.MP1 : Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP3: Construct viable arguments and critique the reasoning of others.

CCSS.Math.Content.HSA-SSE.A.: Interpret expressions that represent a quantity in terms of its context.

CCSS.Math.Content.HSA-CED.A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

THE ESSENTIAL UNDERSTANDING *(What is the overarching idea students will understand as a result of this lesson?*	THE ESSENTIAL QUESTION *(What question will be asked to lead students to "uncover" the Essential Understanding)*
Systems manipulate movement	***How do systems manipulate movement?***

CONTENT KNOWLEDGE (What factual information will students learn in this lesson?)	PROCESS SKILLS (What will students be able to do as a result of this lesson?)
• Roller coasters are designed using physics. • Roller Coasters use potential and kinetic energy • Roller coasters start by using potential energy. • Energy is conserved within a system • Energy can change from potential to kinetic	• Preserve to solve a problem • Work in teams collaboratively • Justify reasoning and articulate it to others • Explain the laws of energy conservation. • Read to find information around a particular concept.

GUIDING QUESTIONS

What questions will be asked to support instruction?

Include both "lesson plan level" questions as well as questions designed to guide students to the essential understanding

Pre-Lesson Questions:	During Lesson Questions:	Post Lesson Questions:
• **What is a system?** • **What do you think of when you hear the word systems?** • **What is movement?** • **What do you think of when you hear movement?** • **What is energy?** • **What are the types of energy?** • **What are the ways energy can change?** • **What is a roller coaster?** • **How are roller coasters designed?** • **What types of energy do roller coasters use?**	• **What stands out as a system and or movement in the article?** • **What types of systems did you find that will impact roller coasters?** • **What types of items did you find that will impact movement?** • **How could you group these systems?** • **What would you title your groups?** • **Why did you group these items this way?** • **Were there any systems your group felt could be grouped differently?** • **How would you re-group these items?** • **What are things you found in common/ different about these systems?** • **How could you group the items around movement?**	• **What systems did you find?** • **What types of movement did you find?** • **How do the systems relate to movement?** • **How do systems manipulate movement?** • **Which system do you think will be the most important when creating your roller coaster? Why?** • **Which systems will have little effect on our roller coasters?** • **What type of energy is involved in building a roller coaster?** •

DIFFERENTIATION

(Describe how the planned learning experience has been modified to meet the needs of gifted learners. Note: Modifications may be in one or more of the areas below. Only provide details for the area(s) that have been differentiated for this lesson.

Content	Process	Product	Learning Environment
	Students engage in in-depth critical thinking as they analyze the different systems that are a part of a roller coaster and how those systems effect changes in movement. They do this through grouping and re-grouping the concepts.		

PLANNED LEARNING EXPERIENCES

(What will the teacher input? What will the students be asked to do? For clarity, please provide detailed instructions)

Engage and Connect - *This phase focuses on piquing students' interest and helping them access prior knowledge. This is the introduction to the lesson that motivates or hooks the students.*

Ice Breaker/ Engage: 4 corners. Students will be given a "ticket" when they enter the room and will fill in the following information. In box 1: they will draw pictures that show their interests. Box 2: What do you think powers a roller coaster? Box 3: What do you know about energy? Box 4: Have you ever been on a roller coaster? Do you enjoy riding roller coasters?

Explore - *In this phase, the students have experiences with the concepts and ideas of the lesson. Students are encouraged to work together without direct instruction from the teacher. The teacher acts as a facilitator. Students observe, question, and investigate the concepts to develop fundamental awareness of the nature of the materials and ideas.*

Listing: *Students will read an article from How things are made: Roller Coasters. This article explains the physics behind a roller coaster. As students read they will be asked to list words/ phrases that relate to systems, movement or the relationship between systems and movement.*

Students will then share their list and we will make a comprehensive list on the board for the class to use.

Explain - *Students communicate what they have learned so far and figure out what it means. This phase also provides an opportunity for teachers to directly introduce a concept, process, or skill to guide students toward a deeper understanding.*

Grouping and Labeling:

Students will work with groups of approximately 4. They will decide which items from the list should go together because they are alike in some way. They will create at least three different groups and they cannot use any of the items twice. Students will be asked to put a label on each of the groups they created.

Elaborate —*Allow students to use their new knowledge and continue to explore its implications. At this stage students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them in new ways*

Subsuming, Re-Grouping and Renaming:

Student groups will be challenged to regroup items. The new groups must be with new categories but the rules will change. Students will t able to use items in multiple groups. The categories must be different than the ones previously created. They must have at least two categories.

Each group will be asked to share their categories.

Evaluate: *This phase assesses both learning and teaching and can use a wide variety of informal and formal assessment strategies.*

The students will be asked to explain the relationship between systems and how they manipulate movement. Student groups will be asked to choose which system they read about they feel is going to be the most important when it comes to building a rollercoaster with the top speed. They will be asked to defend why they think that system will have the largest impact on the movement of their rollercoaster.

(Students will start lesson plan 2 right away if time allows so they can start on the building processes) During lesson plan 2 the students are introduced to the performance task.

TEACHER NAME	Lesson #
Sherry Barnett	2

MODEL	CONTENT AREA	GRADE LEVEL
Creative Problem Solving	STEM	7-9th

CONCEPTUAL LENS	LESSON TOPIC
Systems	Roller Coasters

LEARNING OBJECTIVES *(from State/Local Curriculum)*

PSc.1.1: Understand motion in terms of speed, velocity, acceleration, and momentum.

PSc.1.2: Understand the relationship between forces and motion**.**

PSc.3.1: Understand types of energy, conservation of energy and energy transfer.

CCSS.MATH.PRACTICE.MP1 : Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP3: Construct viable arguments and critique the reasoning of others.

CCSS.Math.Content.HSA-SSE.A.: Interpret expressions that represent a quantity in terms of its context.

CCSS.Math.Content.HSA-CED.A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

THE ESSENTIAL UNDERSTANDING *(What is the overarching idea students will understand as a result of this lesson?*	THE ESSENTIAL QUESTION *(What question will be asked to lead students to "uncover" the Essential Understanding)*
Systems manipulate movement	***How do systems manipulate movement?***

CONTENT KNOWLEDGE (What factual information will students learn in this lesson?)	PROCESS SKILLS (What will students be able to do as a result of this lesson?)
• Roller Coasters are designed using potential and kinetic energy. • Energy is conserved within a system. • Roller Coasters velocity is at its maximum after the first hill. • Energy can be transferred multiple times within a system.	• Preserve to solve a problem • Work in teams collaboratively • Justify reasoning and articulate it to others • Persevere a design processes • Explain the laws of energy conservation. • Calculate Potential and Kinetic Energy. • Create a product based on a design • Analyze outcomes and re-design to improve the end product

GUIDING QUESTIONS *What questions will be asked to support instruction?* *Include both "lesson plan level" questions as well as questions designed to guide students to the essential understanding*		
Pre-Lesson Questions:	**During Lesson Questions:**	**Post Lesson Questions:**
What is design? What is a challenge? What types of systems are used in roller coasters? What movement occurs in roller coasters? How are systems and movement related in roller coasters? What do you think the designers of roller coasters do before building? What types of energy do you think are used when creating a roller coaster? How is energy used and conserved on a roller coaster? How many times do you think designs are tested? What is perseverance?	What changes do you think should be made to your design? Why would you make these changes? What are some of the major issues in your way of being able to build your rollercoaster? What is the biggest challenge you are facing? How are you going to move past the challenges? What other materials would be helpful to have to build the roller coaster? Which system do you think changes need to be made to adjust the movement of your roller coaster?	What was the most challenging part of the experience? How did you work through your challenges? How did your product turn out compared to you original design, What materials would have helped the process? How were different systems used in your Roller Coaster? How did you use what you know about the systems involved in building a roller coaster to make adjustments to your design? How did you use different systems to manipulate the movement in your roller coaster? What is the relationship between systems and movement?

DIFFERENTIATION *(Describe how the planned learning experience has been modified to meet the needs of gifted learners. Note: Modifications may be in one or more of the areas below. Only provide details for the area(s) that have been differentiated for this lesson.*			
Content	**Process**	**Product**	**Learning Environment**
	This lesson allows for critical thinking and perseverance. Students will lead the lesson and have a freedom of design and material choice. This lesson will allow for leadership and creativity that will differ for each student. It also will bring out strengths of each student.	**Students will be creating their own products based on group designs. Each group product will vary based on materials they picked and what type of design they came up with.**	**Students are working in collaborative groups. They will have to take on roles within their groups to make sure they can complete the task.**

PLANNED LEARNING EXPERIENCES

(What will the teacher input? What will the students be asked to do? For clarity, please provide detailed instructions)

Engage and Connect - *This phase focuses on piquing students' interest and helping them access prior knowledge. This is the introduction to the lesson that motivates or hooks the students.*

In groups students will go to the website:
https://www.learner.org/exhibits/parkphysics/coaster/

Students will use the website to design a roller coaster and see if it will work. They will be asked to record what worked for them and what did not. Group will be asked to answer pre-lesson questions and the class will have a discussion around the pre-lesson questions.

Explore - *In this phase, the students have experiences with the concepts and ideas of the lesson. Students are encouraged to work together without direct instruction from the teacher. The teacher acts as a facilitator. Students observe, question, and investigate the concepts to develop fundamental awareness of the nature of the materials and ideas.*

***Mess Finding**: Students will be introduced to their performance task:* Carolina Cost Theme park is looking to create the new biggest and best roller coaster! They want to have a top speed roller coaster that also allows for people to enjoy a long ride with exciting twists and turns. They are asking you, the roller coaster engineers, to design a roller coaster for their theme park that will make everyone want to come.

You will need to design a prototype of the roller coaster and explain the physics behind how it works. They are looking forward to seeing the calculations of how they will know this roller coaster will hit the top speeds as well as having an understanding of how the design uses energy to create the best thrills.

Students will be introduced to the performance task and asked: What are things you know, what you still need to know.

Fact Finding: Students will be allowed to view the materials they will have to use when designing their roller coasters. They will not be able to touch any materials but just view what will be provided.

Explain - *Students communicate what they have learned so far and figure out what it means. This phase also provides an opportunity for teachers to directly introduce a concept, process, or skill to guide students toward a deeper understanding.*

Problem Finding: Students will begin working through how they will design a rollercoaster to work with a marble. They will answers the during lesson questions about how different systems will affect the movement in their roller coaster. We will discuss what types of obstacles they may run into during the design process. Which of the systems that we learned about do they think will be the most important to think about during the design? Which ones will have the least effect on the coaster?

Idea Finding: Students will be given time to start coming up with designs for their roller coasters. Each student in the group should come up with at least one initial design. The group will then have to choose which design they think will work the best to create the fastest and longest lasting roller coaster. They should be able as a group to explain why they think it would be the best design.

Elaborate —*Allow students to use their new knowledge and continue to explore its implications. At this stage students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them in new ways*

Idea Finding: Students will start building based on the design they feel is best.

Evaluate: *This phase assesses both learning and teaching and can use a wide variety of informal and formal assessment strategies.*

*(*This lesson will be continued on the next day)

Students will be asked to right a reflection about their current design and which parts they think are going well/ which parts will need improvement. In the reflection they should explain which system will need to be manipulated in order to make improvements to their roller coaster. (This will be done individually)

TEACHER NAME	Lesson #
Sherry Barnett	3

MODEL	CONTENT AREA	GRADE LEVEL
Creative Problem Solving/ VTS	**STEM**	**7-9th**

CONCEPTUAL LENS	LESSON TOPIC
Systems	**Roller Coasters**

LEARNING OBJECTIVES *(from State/Local Curriculum)*

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CONTENT KNOWLEDGE (What factual information will students learn in this lesson?)	PROCESS SKILLS (What will students be able to do as a result of this lesson?)
• Roller Coasters are designed using potential and kinetic energy. • Energy is conserved within a system. • Roller Coasters velocity is at its maximum after the first hill. • Energy can be transferred multiple times within a system.	• Preserve to solve a problem • Work in teams collaboratively • Justify reasoning and articulate it to others • Persevere a design processes • Explain the laws of energy conservation. • Calculate Potential and Kinetic Energy. • Create a product based on a design • Analyze outcomes and re-design to improve the end product

GUIDING QUESTIONS *What questions will be asked to support instruction?* *Include both "lesson plan level" questions as well as questions designed to guide students to the essential understanding*		
Pre-Lesson Questions:	**During Lesson Questions:**	**Post Lesson Questions:**
What is design? What is a challenge? What is energy? What types of systems did we use yesterday? What type of movement did you observe in your rollercoaster? How systems were related to the movement in the roller coaster you started building? Looking at your reflection from yesterday, what parts of your rollercoaster need improvement? What system do you think needs to be manipulated in order to improve your rollercoaster? How is energy used and conserved on a roller coaster? How many times do you think designs are tested?	What changes do you think should be made to your design? Why would you make these changes? What are some of the major issues in your way of being able to build your rollercoaster? What is the biggest challenge you are facing? How are you going to move past the challenges? What other materials would be helpful to have to build the roller coaster? Which system do you think changes need to be made to adjust the movement of your roller coaster?	What was the most challenging part of the experience? How did you work through your challenges? How did your product turn out compared to you original design, What materials would have helped the process? How were different systems used in your Roller Coaster? How did you use what you know about the systems involved in building a roller coaster to make adjustments to your design? How did you use different systems to manipulate the movement in your roller coaster? What is the relationship between systems and movement?

DIFFERENTIATION *(Describe how the planned learning experience has been modified to meet the needs of gifted learners. Note: Modifications may be in one or more of the areas below. Only provide details for the area(s) that have been differentiated for this lesson.*			
Content	**Process**	**Product**	**Learning Environment**
	This lesson allows for critical thinking and perseverance. Students will lead the lesson and have a freedom of design and material choice. This lesson will allow for leadership and creativity that will differ for each student. It also will bring out strengths of each student.	**Students will be creating their own products based on group designs. Each group product will vary based on materials they picked and what type of design they came up with.**	**Students are working in collaborative groups. They will have to take on roles within their groups to make sure they can complete the task.**

PLANNED LEARNING EXPERIENCES

(What will the teacher input? What will the students be asked to do? For clarity, please provide detailed instructions)

Engage and Connect - *This phase focuses on piquing students' interest and helping them access prior knowledge. This is the introduction to the lesson that motivates or hooks the students.*

Students will look at the following image:

Students will be asked: What do you see? What makes you say that? What else do you see?
The teacher should paraphrase what students are saying and point to/ acknowledge the areas they are referring to.

Explore - *In this phase, the students have experiences with the concepts and ideas of the lesson. Students are encouraged to work together without direct instruction from the teacher. The teacher acts as a facilitator. Students observe, question, and investigate the concepts to develop fundamental awareness of the nature of the materials and ideas.*

Solution Finding: Students will be asked to think about their reflections from the previous day. As a group they should compare their reflections and see if there are any similar thoughts in how to make changes to their roller coasters. They should discuss why they think these changes would make the roller coaster better

Explain - *Students communicate what they have learned so far and figure out what it means. This phase also provides an opportunity for teachers to directly introduce a concept, process, or skill to guide students toward a deeper understanding.*

Solution Finding: The class will then discuss some of the during lesson questions. Groups will be asked to re-design if needed and explain what systems they think their re-design may affect.

Elaborate —*Allow students to use their new knowledge and continue to explore its implications. At this stage students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them in new ways*

Acceptance Finding: Now that students have come up with a new design they will be asked to come up with a plan to make this happen. What changes are they going to make and why? Why does the group think this is going to be the best design? They will come up with group roles to keep the group focused and on task to complete building their roller coasters.

Evaluate: *This phase assesses both learning and teaching and can use a wide variety of informal and formal assessment strategies.*

Students will be asked to consider their re-design and the systems the felt it may have impacted. After being able to see changes in their roller coaster they should answer the following questions:

What kinds of results did you see from the changes you made? Which systems do you think were changed and what outcomes did you get? How has the movement of the marble changed since you have changed these systems? What changes would you make now that you have tested your designs? How do systems manipulate movement?

TEACHER NAME	Lesson #
Sherry Barnett	4

MODEL	CONTENT AREA	GRADE LEVEL
PBL	STEM	Rising 7 -9th

CONCEPTUAL LENS	LESSON TOPIC
Systems	Roller Coasters

LEARNING OBJECTIVES *(from State/Local Curriculum)*

PSc.1.1: Understand motion in terms of speed, velocity, acceleration, and momentum.

PSc.1.2: Understand the relationship between forces and motion**.**

PSc.3.1: Understand types of energy, conservation of energy and energy transfer.

CCSS.MATH.PRACTICE.MP1 : Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP3: Construct viable arguments and critique the reasoning of others.

CCSS.Math.Content.HSA-SSE.A.: Interpret expressions that represent a quantity in terms of its context.

CCSS.Math.Content.HSA-CED.A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

THE ESSENTIAL UNDERSTANDING *(What is the overarching idea students will understand as a result of this lesson?*	THE ESSENTIAL QUESTION *(What question will be asked to lead students to "uncover" the Essential Understanding)*
Systems Manipulate Movement	***How do systems manipulate movement?***

CONTENT KNOWLEDGE (What factual information will students learn in this lesson?)	PROCESS SKILLS (What will students be able to do as a result of this lesson?)
• Kinetic Energy, Potential Energy, Velocity, friction and forces are involved in roller coasters and effect the movement. • Velocity can be calculated using the formula d/t • Potential and Kinetic energy must equal the total energy in the system. • Potential energy is calculated using the formula PE=mgh • Kinetic energy can be calculated using the formula 1/2mv^2	• Preserve to solve a problem • Work in teams collaboratively • Justify reasoning and articulate it to others • Explain the laws of energy conservation. • Calculate Potential and Kinetic Energy. • Calculate Velocity • Analyze outcomes and what changes can be made to affect outcomes.

GUIDING QUESTIONS *What questions will be asked to support instruction?* *Include both "lesson plan level" questions as well as questions designed to guide students to the essential understanding*		
Pre-Lesson Questions:	**During Lesson Questions:**	**Post Lesson Questions:**
• What systems are part of this problem? • What types of movement are we seeing? • How are the systems related to the movement? • Given the situation what is information that you know? • What do you need to know? • What are possible steps we may need to take to find the information we need? • What questions do you have about the scenario that was given to you? • What formulas do we need to know and use? • What assumptions do we need to make? • What else do we need to know before we can begin?	• How could you manipulate the formula to find what you need? • What information are you given? • What are you trying to find? • What do we know about the laws of conservation of energy? How can what you know help you to find energy in a system? • When is potential energy the greatest? When is it the least? • What relationship does kinetic energy have with potential energy? • How does potential energy effect movement? • What types of systems are manipulating movement?	• How does change the velocity change the kinetic energy? • How does changing the mass effect the potential and kinetic energy? • What are ways to increase potential energy? • What would happen to the kinetic energy if you were to double the velocity of the car? • How does changing parts of a system manipulate the movement in the system? • How do systems manipulate movement?

DIFFERENTIATION *(Describe how the planned learning experience has been modified to meet the needs of gifted learners. Note: Modifications may be in one or more of the areas below. Only provide details for the area(s) that have been differentiated for this lesson.*			
Content	**Process**	**Product**	**Learning Environment**
	Students will engage in in-depth critical thinking through the problem. They will be asked to apply and analyze findings to make a decision and recommendations. Students can also be given varying amounts of support during the monitoring phase.	**Students will have an option in how their product is presented. They will be able to present their findings in different methods.**	

PLANNED LEARNING EXPERIENCES

(What will the teacher input? What will the students be asked to do? For clarity, please provide detailed instructions)

Engage and Connect - *This phase focuses on piquing students' interest and helping them access prior knowledge. This is the introduction to the lesson that motivates or hooks the students.*

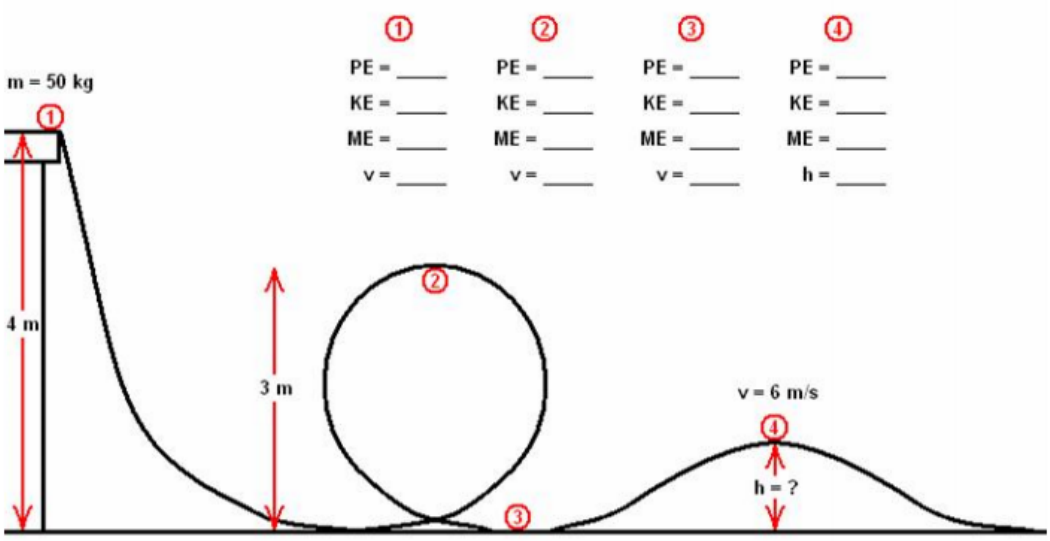
Students will enter the room and see the following diagram on the board: https://wtvi.pbslearningmedia.org/resource/hew06.sci.phys.maf.rollercoaster/energy-in-a-roller-coaster-ride/#.WVEfF1XyvZ5

Students will be asked where they think the maximum potential energy and kinetic energy are located and to explain their reasoning? They will also be asked what they think the relationship between potential and kinetic energy is?

After students have made predictions we will watch the virtual roller coaster.

Explore - *In this phase, the students have experiences with the concepts and ideas of the lesson. Students are encouraged to work together without direct instruction from the teacher. The teacher acts as a facilitator. Students observe, question, and investigate the concepts to develop fundamental awareness of the nature of the materials and ideas.*

Problem Engagement: Students will be given the problem: Carolina Coasters was given a design for a roller coaster but they are not sure it will actually work because information is missing. They are asking you to use the following diagram to help them fill in the information and decide if the roller coaster will work correctly.



Inquiry and Investigation: After reading the problem students will be asked the pre-lesson questions.

Explain - *Students communicate what they have learned so far and figure out what it means. This phase also provides an opportunity for teachers to directly introduce a concept, process, or skill to guide students toward a deeper understanding.*

Problem Definition: Students will be asked to start solving the problem with their groups. Students may need to look up formulas in order to be able to solve the problems. As they work groups will be asked guiding questions (pre-lesson questions). Questions asked during the monitoring phase will be asked based on how each group is progressing towards solving the problem.

Elaborate —*Allow students to use their new knowledge and continue to explore its implications. At this stage students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them in new ways*

Problem Resolution: As a class groups will be strategically asked to share and show their work on solving for the missing information. There are many methods on how to solve and show work so each group will be asked to present a part of what they are doing to solve the problem. The teacher would then have the opportunity to address any common misconceptions as well as allow groups to showcase work and guide other groups that may be using different methods. During this time students will be pointed to seeing the relationship between the systems in the roller coaster and how they are related.

Evaluate: *This phase assesses both learning and teaching and can use a wide variety of informal and formal assessment strategies.*

Problem Debriefing: *Students will be shown the same roller coaster form the beginning of class again* *https://wtvi.pbslearningmedia.org/resource/hew06.sci.phys.maf.rollercoaster/energy-in-a-roller-coaster-ride/#.WVEfF1XyvZ5*

The group will then do an all talk about: How do systems manipulate movement? First students will be asked to specifically think about how this relates to roller coasters. Groups will be asked to come up with another example of when/how systems can manipulate movement.

How it works: Roller Coasters

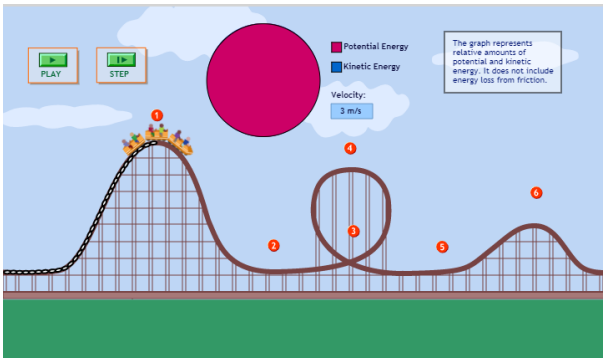
If you're studying physics, there are few more exhilarating classrooms than a roller coaster. Roller coasters are driven almost entirely by basic inertial, gravitational and centripetal forces, all manipulated in the service of a great ride. Amusement parks keep upping the ante, building faster and more complex roller coasters, but the fundamental principles at work remain the same.
In this article, we'll examine the principles that keep coaster cars flying around on their tracks. We'll also look at the hardware that keeps everything running, as well as the forces that make the ride so much fun.

The amusement-park industry has experienced a coaster boom of sorts in the past 15 years or so. New catapult launching techniques, hanging-train designs and other technological developments have opened up a world of options for designers. In recent years, designers have introduced coasters that have you lying flat against the train car so you feel as if you are flying, and coasters that shoot you down long stretches of spiraled track. "Fourth dimension" coasters spin or rotate your seat as the ride twists, turns and free-falls. In this article, we'll also keep you in the loop on all the newest features and innovations.

At first glance, a roller coaster is something like a passenger train. It consists of a series of connected cars that move on tracks. But unlike a passenger train, a roller coaster has no engine or power source of its own. For most of the ride, the train is moved by gravity and momentum. To build up this momentum, you need to get the train to the top of the first hill (the lift hill) or give it a powerful launch.

Roller Coaster Physics

The purpose of the coaster's initial ascent is to build up a sort of reservoir of potential energy. The concept of potential energy, often referred to as energy of position, is very simple: As the coaster gets higher in the air, gravity can pull it down a greater distance. You experience this phenomenon all the time -- think about driving your car, riding your bike or pulling your sled to the top of a big hill. The potential energy you build going up the hill can be released as kinetic energy -- the energy of motion that takes you down the hill.Once you start cruising down that first hill, gravity takes over and all the built-up potential energy changes to kinetic energy. Gravity applies a constant downward force on the cars.



At the top of the first lift hill (1) there is maximum potential energy because the train is as high as it gets. As the train starts down the hill, this potential energy is converted into kinetic energy -- the

train speeds up. At the bottom of the hill (2), there is maximum kinetic energy and little potential energy. The kinetic energy propels the train up the second hill, building up the potential-energy level. As the train enters the loop-the-loop (3), it has a lot of kinetic energy and not much potential energy. The potential-energy level builds as the train speeds to the top of the loop (4), but it is soon converted back to kinetic energy as the train leaves the loop.

The coaster tracks serve to channel this force -- they control the way the coaster cars fall. If the tracks slope down, gravity pulls the front of the car toward the ground, so it accelerates. If the tracks tilt up, gravity applies a downward force on the back of the coaster, so it decelerates.
Since an object in motion tends to stay in motion (Newton's first law of motion), the coaster car will maintain a forward velocity even when it is moving up the track, opposite the force of gravity. When the coaster ascends one of the smaller hills that follows the initial lift hill, its kinetic energy changes back to potential energy. In this way, the course of the track is constantly converting energy from kinetic to potential and back again.

This fluctuation in acceleration is what makes roller coasters so much fun. In most roller coasters, the hills decrease in height as you move along the track. This is necessary because the total energy reservoir built up in the lift hill is gradually lost to friction between the train and the track, as well as between the train and the air. When the train coasts to the end of the track, the energy reservoir is almost completely empty. At this point, the train either comes to a stop or is sent up the lift hill for another ride. At its most basic level, this is all a roller coaster is -- a machine that uses gravity and inertia to send a train along a winding track. Next, we'll look at the various sensations you feel during a roller coaster ride, what causes them and why they're so enjoyable.

In the last few sections, we looked at the forces and machinery that send roller coasters rocketing around elaborate courses. As you move over the hills, valleys and loops of the track, the forces on you seem to change constantly, pulling you in all directions. But why is this rollicking movement so enjoyable (or, for some people, so nauseating)?

To understand the sensations you feel in a roller coaster, let's look at the basic forces at work on your body. Wherever you are on Earth, gravity is pulling you down toward the ground. But the force you actually notice isn't this downward pull -- it's the upward pressure of the ground underneath you. The ground stops your descent to the center of the planet. It pushes up on your feet, which push up on the bones in your legs, which push up on your rib cage and so on. This is the feeling of weight. At every point on a roller-coaster ride, gravity is pulling you straight down.

The other force acting on you is acceleration. When you are riding in a coaster car that is traveling at a constant speed, you only feel the downward force of gravity. But as the car speeds up or slows down, you feel pressed against your seat or the restraining bar.

You feel this force because your inertia is separate from that of the coaster car. When you ride a roller coaster, all of the forces we've discussed are acting on your body in different ways.
Newton's first law of motion states that an object in motion tends to stay in motion. That is, your body will keep going at the same speed in the same direction unless some other force acts on you to change that speed or direction. When the coaster speeds up, the seat in the cart pushes you forward, accelerating your motion. When the cart slows down, your body naturally wants to keep

going at its original speed. The harness in front of you accelerates your body backward, slowing you down.

Roller Coasters and Your Body

Your body feels acceleration in a funny way. When a coaster car is speeding up, the actual force acting on you is the seat pushing your body forward. But, because of your body's inertia, you feel a force in front of you, pushing you into the seat. You always feel the push of acceleration coming from the opposite direction of the actual force accelerating you.
This force (for simplicity's sake, we'll call it the acceleration force) feels exactly the same as the force of gravity that pulls you toward the Earth. In fact, acceleration forces are measured in g-forces, where 1 g is equal to the force of acceleration due to gravity near the Earth's surface (9.8 m/s2, or 32 ft/s2).

A roller coaster takes advantage of this similarity. It constantly changes its acceleration and its position to the ground, making the forces of gravity and acceleration interact in many interesting ways. When you plummet down a steep hill, gravity pulls you down while the acceleration force seems to be pulling you up. At a certain rate of acceleration, these opposite forces balance each other out, making you feel a sensation of weightlessness -- the same sensation a skydiver feels in free fall. If the coaster accelerates downward fast enough, the upward acceleration force exceeds the downward force of gravity, making you feel like you're being pulled upward. If you're accelerating up a steep hill, the acceleration force and gravity are pulling in roughly the same direction, making you feel much heavier than normal. If you were to sit on a scale during a roller coaster ride, you would see your "weight" change from point to point on the track.
At the top of a hill in a conventional coaster, inertia may carry you up, while the coaster car has already started to follow the track down. Let go of the safety bar, and you'll actually lift up out of your seat for an instant. Coaster enthusiasts refer to this moment of free fall as "air time."

Loop-the-Loops

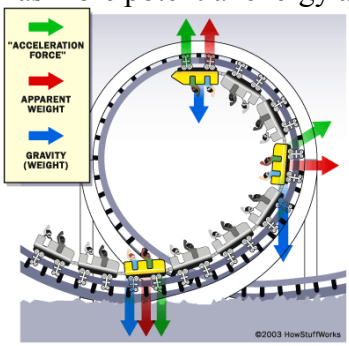
As you go around a loop-the-loop, your inertia not only produces an exciting acceleration force, but it also keeps you in the seat when you're upside down. A roller coaster loop-the-loop is a sort of **centrifuge**, just like a merry-go-round. In a merry-go-round, the spinning platform pushes you out in a straight line away from the platform. The constraining bar at the edge of the merry-go-round stops you from following this path -- it is constantly accelerating you toward the center of the platform.

The loop-the-loop in a roller coaster acts exactly the same way as a merry-go-round. As you approach the loop, your **inertial velocity** is straight ahead of you. But the track keeps the coaster car, and therefore your body, from traveling along this straight path. The force of your acceleration pushes you from the coaster-car floor, and your inertia pushes you into the car floor. Your own outward inertia creates a sort of false gravity that stays fixed at the bottom of the car even when you're upside down. You need a safety harness for security, but in most loop-the-loops, you would stay in the car whether you had a harness or not.

As you move around the loop, the net force acting on your body is constantly changing. At the very bottom of the loop, the acceleration force is pushing you down in the same direction as gravity. Since both forces push you in the same direction, you feel especially heavy at this point. As you move straight up the loop, gravity is pulling you into your seat while the acceleration force is pushing you into the floor. You feel the gravity pulling you into your seat, but (if your eyes are still open) you can see that the ground is no longer where it should be.

At the top of the loop, when you're completely upside down, gravity is pulling you out of your seat, toward the ground, but the stronger acceleration force is pushing you into your seat, toward the sky. Since the two forces pushing you in opposite directions are nearly equal, your body feels very light. As in the sharp descent, you are almost weightless for the brief moment when you are at the top of the loop.

In a loop-the-loop, the intensity of the acceleration force is determined by two factors: the speed of the train and the angle of the turn. As the train enters the loop, it has maximum kinetic energy -- that is, it is moving at top speed. At the top of the loop, gravity has slowed the train down somewhat, so it has more potential energy and less kinetic energy -- it is moving at reduced speed.



Originally, roller-coaster designers made circle-shaped loops. In this design, the angle of the turn is constant all the way around. In order to build an acceleration force strong enough to push the train into the track at the top of the loop, they had to send the train into the loop at a fairly high rate of speed (so it would still be going pretty fast at the top of the loop). Greater speed meant a much greater force on the rider as he entered the loop, which could be fairly uncomfortable.

The **teardrop** design makes it much easier to balance these forces. The turn is much sharper at the very top of the loop than it is along the sides. This way, you can send the train through the loop fast enough that it has an adequate acceleration force at the top of the loop, while the teardrop shape creates a reduced acceleration force along the sides. This gives you the force you need to keep everything running, without applying too much force where it might be dangerous.

Unit Resources:

The following are additional resources that may be used to supplement the unit. The unit could be extended by adding additional requirements and calculations to go along with the roller coasters as well.

Examples of additional requirements/ contests to add in for extending the unit:

- Include a written or draw diagram that shows which type of energy the marble has/ is using during each section of the roller coaster.
- Create advertisements and marketing plans for the roller coaster
- Calculate costs to build
- Include additional contests:
    - **Best scenery:** Lots of quality scenery covering the entire coaster and platform. Simple but clever or well done, campy, designs show more creativity -especially when they support the name and theme of your coaster.
    - **Best Theme:** What's the name of your roller coaster? Does your scenery support this theme? Does the design support your theme? Is there a coolness or cleverness factor to your name?
    - **Most complex design**: Wow. We're looking at the loops, twists ,dips, turns, etc

Additional Resources

How it works article: The article used for Unit plan 1 is attached but was pulled from the following website which has additional information that may be useful for the unit.
http://science.howstuffworks.com/engineering/structural/roller-coaster3.htm

Engineering Thrills Videos 1-6: Discovery channel did a mini-series on designing roller coasters and how they work. These 6 short videos may work as supplemental material for students to understand the design processes. https://www.youtube.com/watch?v=dBdj7Lcz2Xc

Paper Loop Lab: This 2 part resource helps students better understand how to design and build a loop for their roller coaster. It also guides students through the calculations
http://www.mrwaynesclass.com/ProjectCoaster/PaperCoasterLabPart1_of_2.pdf
http://www.mrwaynesclass.com/ProjectCoaster/PaperCoasterLabPart2_of_2.pdf

Tutorials and Examples: This website includes examples of paper roller coasters and tutorials on how to build supports, tracks and loops. http://www.instructables.com/id/Paper-Roller-Coasters-/

Average Speed Lab: This lab is used after the roller coaster is built and helps students understand how to calculate average speed.
http://paperrollercoasters.com/calculating_average_speed_fillable.pdf

Launch Systems: This website includes articles about roller coasters and different types of system's they use. http://www.coaster101.com/2013/10/08/coasters-101-launch-systems/

Paper Roller Coaster Video Tutorials: Students may find the "How to" videos posted on this website helpful if they are struggling with designing loops, curves or funnels. http://www.mrwaynesclass.com/ProjectCoaster/

Engineering and Design processes in the classroom: This short video helps provide ways to use this process effectively in the classroom. https://www.teachingchannel.org/videos/engineering-design-process