Fun with Roller Coasters!!

Name _____

Group _____

Class _____

Work, Energy, Forces, & Motion

CoMPASS Project 2011-2012
University of Wisconsin-Madison

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CoMPASS
Concept Mapped Project-based Activity Scaffolding System

Name: _____

Class: _____

Teacher: _____

Group: _____

Group Members: _____

_____

_____

_____

School: _____

What Do You Know about Physics?

Directions for making your concept map:

1.List as many words as you can think of that relate to the topics of work, energy, forces, and motion in the "brainstorming box."

2.Start to create a map on the "My Map" page by writing words and drawing a circle around each word.

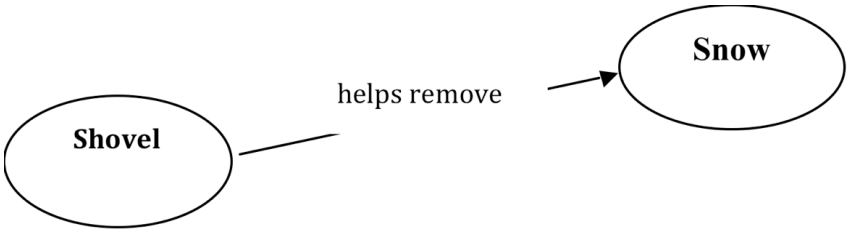
3.Place arrows between the circles to show how words are connected.

4.Explain each connection along every arrow.

Hints and Tips:

- For each concept, think about how it is related to other concepts.
- Don't use only "is a" or "part of" links, but think about how each word is related to other words. For example, "force causes acceleration."

Example of how to set up your map:



Brainstorming Box

My Map

Roller Coaster Design Challenge

The Gonzales family runs a large amusement park. In recent years, attendance at the Gonzales' amusement park has been dropping. The family heard that adding new rides, such as a new roller coaster, can increase park attendance dramatically. The members of the Gonzales family are not experts in physics, so they have put out a call for local scientists and engineers to submit proposals for a new roller coaster. You are a member of a design team, and your challenge is to help the Gonzalez family design a roller coaster!

To design a safe and exciting roller coaster, you will need to understand physics concepts like force, motion, and energy. To better understand the science of roller coasters, you will conduct several science explorations. You will need to use what you learn during these explorations to explain your design to the Gonzales family.

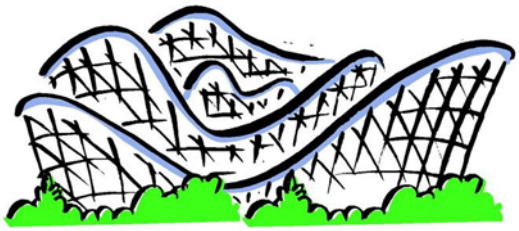
At the end of the unit, you will write a final roller coaster design proposal to the Gonzales family.

Using your understanding of physics and the science of roller coasters you will need to communicate the following:

- The science concepts behind how each section of the roller coaster works
- The science concepts that make your roller coaster exciting
- The science concepts behind what makes your design safe
- The science concepts needed to explain how your roller coaster design is efficient
- The science concepts behind your choice of roller coaster car mass

At a minimum your roller coaster design must include the following four sections:

- A way to lift your car to the initial drop
- An initial drop
- A hill
- A flat section long enough to stop the roller coaster



You must also include a diagram for your ride and identify:

- Each force acting on the people during the ride and its direction
- Energy changes that occur during the ride

Creating Your Dream Team

What's important to you?

- Read the following *Dream Team Collaboration Tips* (DTCTs) below.
- Circle the tips that will be most important for helping your group work together effectively to complete your overall challenge in style by having fun and learning science at the same time.
- Add your own DTCTs below in the space provided.
- Discuss why you think certain tips are important with other members of your group.
- Sign below to indicate that you agree to follow the tips.

The DTCTs:

Tips for your contribution:

•Contribute at least one idea to the team discussion

•Explain your ideas thoroughly and give reasons for your ideas

Tips for Responding to Other Team Members' contributions:

- Actively listen to what other members are sharing!
- Ask them to elaborate or re-explain their ideas if you do not understand their point!
- Ask them how they know! What support or evidence can they share for their idea?
- Think about what you can add to the discussion!

•Other potential DTCTs:

_____

_____

_____

_____

_____

_____

Think Like Scientists and Engineers!

Just like players on a soccer team, scientists and engineers often work in teams to reach their goals. However, instead of kicking around a ball, they "kick around" ideas to try to solve problems. "Kicking around" ideas from scientists' perspective means that they discuss, debate, test, model, argue about, and listen to others' ideas.

You will be working as scientists and engineers in collaborative teams throughout this unit.

I agree to follow the DTCTs, so my team can be a Dream Team!

Student Signature:

_____

Initial Roller Coaster Ideas

Use the space below to create a labeled diagram of your initial ideas for a roller coaster.

Label the different sections of your roller coaster. Then, do your best to identify the forces acting on the riders and the energy changes in those sections.

Remember at a minimum your roller coaster must include the following:

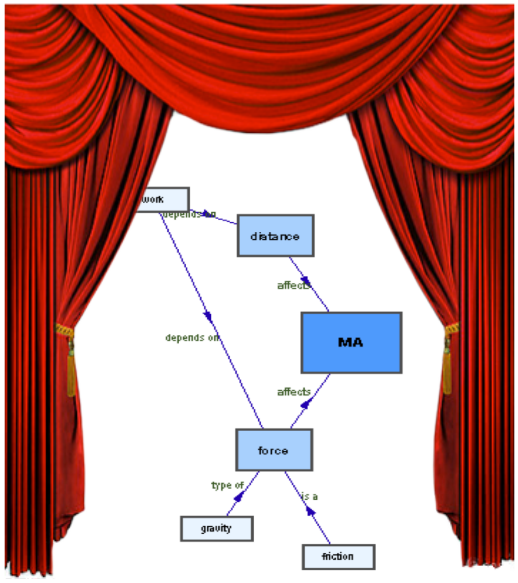
- A way to lift your car to the initial drop
- An initial drop
- A hill
- A flat section long enough to stop the roller coaster car

Explain, using science terms where possible, how your coaster will work and how it is exciting, safe and efficient.

Introducing CoMPASS!!!

The main resource for researching about science concepts that you will need to understand to solve your challenge is the CoMPASS website.

Using and learning from CoMPASS is fun and easy. Your teacher will walk you though the special features that CoMPASS has to offer.



CoMPASS is different from reading a textbook for several reasons because you can:

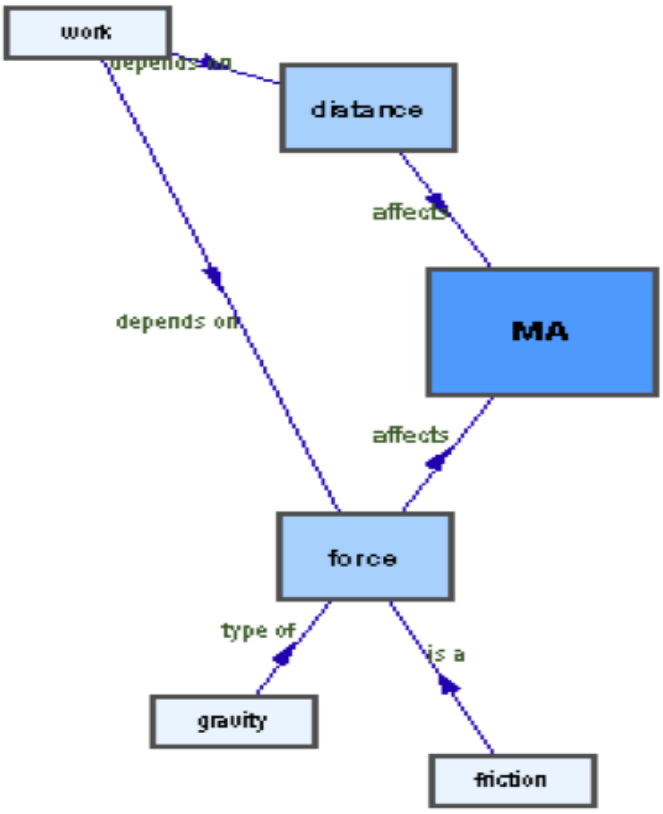
1. Choose the order in which you read the information. If you are thoughtful about choosing concepts to read, you will learn a lot.
2. Use the concept maps to help you make decisions about what information will be most useful to you for solving your challenge.
3. Use different features such as:
   - the "history" link to see the concepts that you have already visited
   - the "definition" link to read general definitions of concepts
   - the links at the top of the page to learn about the same concept in a different topics
4. Visit different pages by clicking on the links in the text or by clicking on concepts in the maps.

Tips for Using CoMPASS:

Think about –

- your questions and goals for using CoMPASS
- how the maps in CoMPASS can help you learn about important science concepts and their relationships
- taking notes in your own words
- your understanding of the physics – if you are stuck, talk to someone!

Exploring Physics Ideas on CoMPASS with the Concept Maps!



Above: *Concept map of MA (mechanical advantage) and its relationships with other concepts*

Understanding the Map in this example:

- MA is the main concept, since it is placed in the largest and darkest box
- the concepts distance and force are most closely related to MA and have been placed closest to the MA box in the second largest and darkest boxes
- work, gravity, and friction are still related to MA, but to a lesser extent, and are placed further away in the smallest and lightest boxes
- the words placed on the arrows between the concepts help you to understand the relationship between the concepts

Hints for Using the Maps:

1. Before clicking on a concept, think about how concepts are related to each other and how these relationships may be important for your challenge.
2. Before moving on to the next concept, think about how the concept you are about to click on might help you to understand the concept you just read about.
3. In your team, discuss which concept you think you should read about next to make sure it will help you to solve your challenge and learn more about physics.

Reading Excursion #1

Ready, Set, Explore!

What design decisions did you make for your Roller Coaster Challenge? Think about your ideas as you and your team explore the CoMPASS website in order to learn more about the scientific meaning of some terms that will be important for your roller coaster explorations and design.

First, discuss with your team and write down what you think each of the following words means:

Weight:_____

_____

Mass:_____

_____

Speed:_____

_____

Velocity:_____

_____

Force:_____

_____

Work:_____

_____

Energy:_____

_____

Think Like Scientists and Engineers!

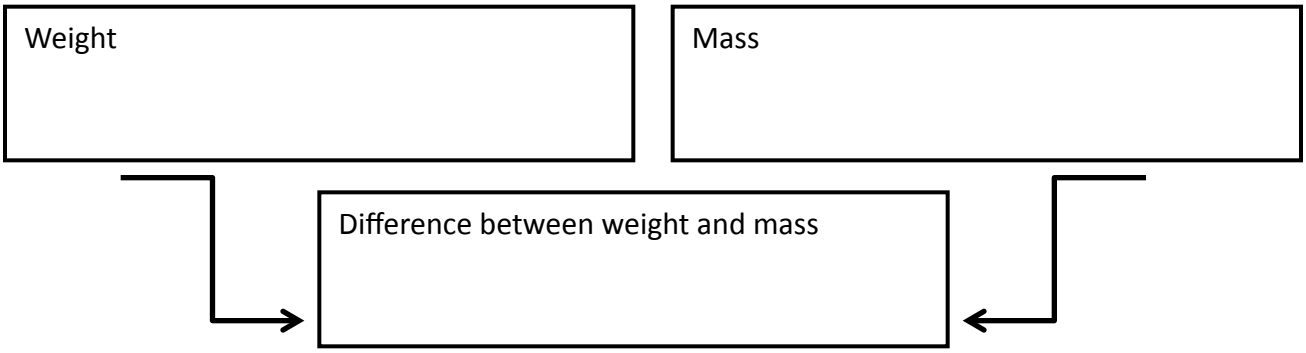
Our everyday understanding and use of words is sometimes very different from how scientists and engineers use them.

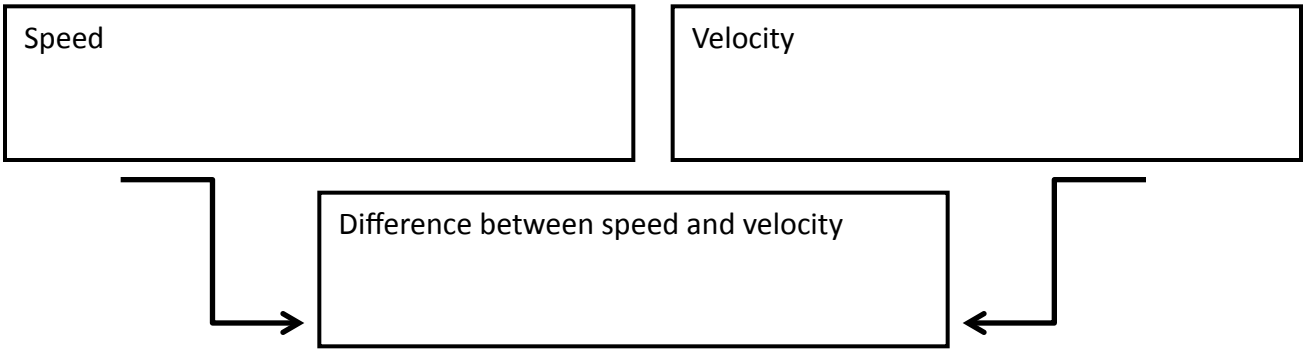
In order to do investigations and create designs, we need to understand the scientific meaning of important concepts.

As you go on this excursion, think about how the scientific meaning of words may be different from the way we think about them and use them in everyday life.

Reading Excursion #1

Now, explore with your team on CoMPASS to find and write the scientific definition of the following pairs of words. Then, provide an explanation of how the words in each pair differ from each other.





Reading Excursion #1

You Decide: While conducting your explorations, it is important that you understand the different kinds of forces acting on the roller coaster car. You will also need to understand the scientific definition of work.

Use the CoMPASS website, the additional websites listed below and your textbook to conduct your work and forces excursion. Remember to take notes from the different websites and your textbook as you read information to help you to understand the scientific definition of work and how forces with different names differ from one another.

www.compassproject.net

www.physics4kids.com/files/motion_intro.html

www.physicsclassroom.com/Class/newtlaws/U2L2b.cfm

For this excursion, watch the video using the following link and think about whether work is being done in each scenario.

www.compassproject.net

Then, investigate different kinds of forces in order to learn about which forces will be acting on the car as you do your roller coaster explorations.

In which video scenarios is work being done? Why?

_____

_____

_____

What is a force?

_____

_____

List the different types of forces you have learned about so far during your reading excursion.

_____

_____

_____

In reading different sources you should:

- evaluate their usefulness and how information fits with your existing ideas
- think about the credibility of the sources that you are reading, especially online resources
- discuss the science ideas you learned from all of the sources with your Dream Team to figure out the best way to answer the questions

Reading Excursion #1

Ready Set Go!

In order to communicate about the different forces acting on an object, scientists and engineers need to have some way to represent the forces they are describing. They do this by using symbols called *vectors.*

Use CoMPASS and the other physics website listed below to read about vectors. Then, answer the question below and practice labeling the vector diagram so that you can start using vectors to label the forces in your roller coaster design.

www.compassproject.net

www.physics4kids.com/files/motion_vectors.html

Think Like Scientists and Engineers!

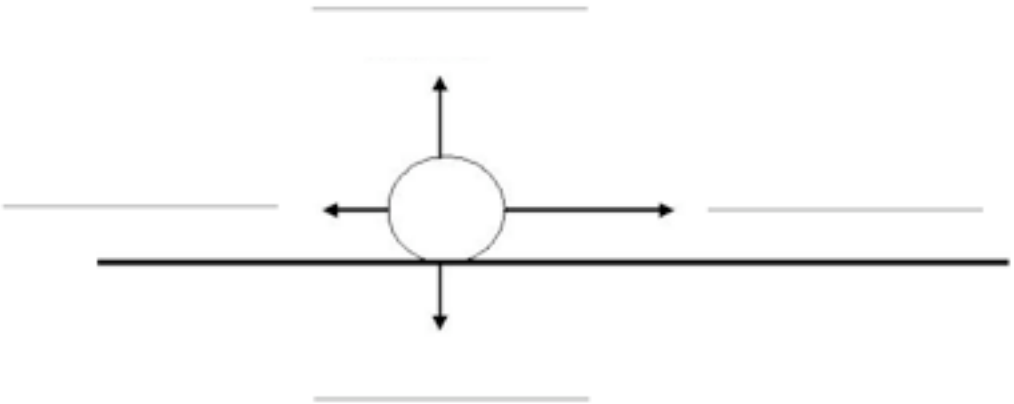
Scientists and engineers use symbols to communicate information in their drawings.

What is a vector?

_____

_____

Vector Diagram: The diagram below represents a ball that has been rolled on a flat surface. On the gray lines below, label the vectors representing the different forces of gravity, friction, normal force, and applied force that are acting on the ball. Remember to use information from the websites and your textbook to help you identify the forces.



Net force is the combination of all forces acting on an object. How does net force relate to the diagram above?

_____

_____

_____

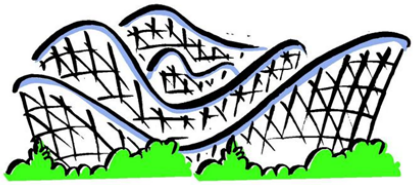
Car Lift Exploration

Did you ever ride a roller coaster? Do you remember how the roller coaster car was lifted to the top of the initial drop? How can you get the roller coaster car and passengers up to the top of the initial drop in your design?

In this exploration you will discover physics concepts that will help you to understand the roles that force, work, energy and efficiency play in this design task.

You will conduct three explorations to understand:

- How the mass of the car affects force, work and energy
- How the height of the initial drop affects work and energy
- How friction affects force, work, energy and efficiency



Using the box below, brainstorm with your team some things that you will need to know about science and physics concepts in order to get your rollercoaster car to the top of the initial drop. Write your ideas below and then share them with your teacher and the rest of the class in a whole class discussion.

Brainstorming Box

Car Lift Exploration

Ready, Set, Explore!

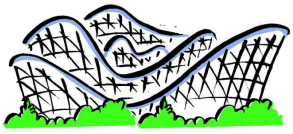
You've just learned the meanings of some concepts that are important for your car lift exploration. Now, think about how mass, height and friction will affect applied force, work, energy and efficiency. Read the statements below and write one of the following on the line provided before the statement:

"A" if you Agree	"D" if you Disagree	"DK" if you Don't Know

Think Like Scientists and Engineers!

Scientists and engineers think about what they know before starting a new exploration.

What do you know about work, force, energy, friction, and efficiency?



Work & Energy Brain Warm Up!

1. _____ If the mass is greater, the applied force needed to lift the cars to the top will be greater.
2. _____ Potential energy is not related to work.
3. _____ If there is friction, some energy will be transformed into less useful forms when doing work.
4. _____ Friction does not affect applied force, work or energy.
5. _____ In lifting the cars to the top of a ramp, work and potential energy will be the same if there is no friction.
6. _____ Smooth surfaces have more friction.
7. _____ The higher the initial drop, the more potential energy the roller coaster car will have at the top.
8. _____ By changing the amount of friction, a roller coaster can be made more efficient.

When you have finished answering the questions on your own, talk with your group about your answers and why you chose them.

What else are you thinking about? Did your conversation spark any other ideas or things you know about physics that were not in the Brain Warm Up statements? Write down other ideas you have.

_____

_____

_____

_____

Our Car Lift Questions

What would you like to know about work, energy, forces, and motion to help you with your Car Lift Exploration and the overall Roller Coaster Challenge?

Brainstorm some questions with your team and write them in the space below.

Think Like Scientists and Engineers!

Questions guide all scientific and engineering investigations. Asking questions helps scientists and engineers to gather evidence for:

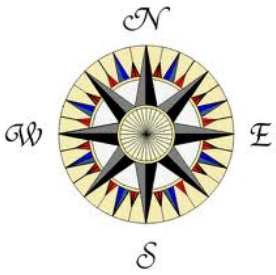
- creating and refining models
- generating explanations
- challenging their current understanding of the science

Hints and Tips:

Think about:

- your goal for this exploration: how mass, height and friction affect the work and energy
- the science concepts relevant to your challenge
- asking a question that starts with "why" or "how"
- going back to your "Brain Warm Up" statements and changing them into questions

Let's Find out more on CoMPASS



Which direction will you go on CoMPASS?

Explore the text and concept maps on CoMPASS to learn more about physics for your Car Lift Exploration! Use the CoMPASS website to help you learn about new science ideas!

As you research, take time to find answers to the questions you brainstormed as a team.

Think Like Scientists and Engineers!

Scientists and engineers often read what others have written about a topic to help guide them in their explorations.

Hints and tips:

Think about:

- using your questions to help you decide what to read
- using the maps in CoMPASS to help you learn and explore important science concepts
- writing notes in your own words, NOT copying text from CoMPASS
- discussing ideas with your group
- discussing how the information will help with your challenge

Car Lift Exploration Hypothesis: About Car Masses

Ready, Set, Explore! In this first exploration, you will learn about how the car mass affects work and energy.

How to make your hypothesis! Before you do the experiment, identify the variables that you will be testing below. Which ones will change and which ones will remain constant? Then, read the *if… then* hypothesis statement below and circle what you think will happen to work and energy when car mass changes.

After making your hypothesis, get together with your team to discuss your hypothesis and explain your thinking and ideas about the science concepts.

Think Like Scientists and Engineers!

Scientists and engineers generate hypotheses *about how one variable will affect another.*

Hints and Tips:

- a hypothesis is written as an *if… then* statement
- when you write a hypothesis you think about how changing one variable affects another
- example: **If** I drop a ball off the roof, **then** it will fall on the ground (because of gravity)

On Your Own: What will happen to work and energy when the mass changes?

In order to identify the relationships between work, energy and mass in your exploration, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

Make a Hypothesis:

If the mass of the car increases, then the work required to lift the car will **increase/decrease/stay the same** (circle one) and the energy needed to lift the car will **increase/decrease/ stay the same** (circle one).

Why do you think this?

_____

_____

In your team:
Discuss each team member's hypothesis and the reasons for your choices.

Let's Investigate Different Roller Coaster Car Masses!

Ready, Set, Explore!

You are now about to conduct a virtual investigation!

For the Car Masses Exploration, you and your team need to understand how the mass of your roller coaster car affects work and energy.

Your teacher will show you how to use the simulation. Use the simulation to explore how the **mass** of the car affects work, energy and force.

Carefully fill out the data chart on the next page as you conduct your Car Mass simulation experiment.

Think like Scientists and Engineers!

Scientists and engineers create models to test their ideas.

Even though models can be very helpful, scientists understand that there are limitations to models – they are made by human beings and are not perfect.

Different models, such as physical and virtual experiments, can give you different kinds of information.

Tips and hints:

- Record data accurately.
- Check that the data the simulation provides makes sense. *If the data does not make sense, re-do a trial.*
- Look for patterns in the data to help you understand the science.
- Talk with others on your team about what you think you are learning from conducting the experiment.

My Roller Coaster Car Masses Data Chart!

Lift Height (m): _____

Trials	Mass (kg)	Applied Force (N)	Work (J)	Potential Energy (J)
1	.2 kg			
2	.4 kg			
3	Greater Mass of your Choice			

Report Out!

Look back at your hypothesis about car mass and work and energy and answer the following:

My hypothesis was **confirmed / not confirmed** (circle one).

Explain why, using specific information from your experiment data above.

_____

_____

_____

_____

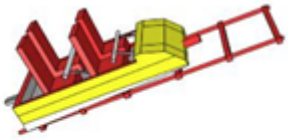
_____

Thinking about Roller Coaster Car Mass

Now look at your data and the images below. What do the patterns in the data tell you about mass and its relationship to work, force and potential energy?

Car A:
Small Mass

Car B:
Medium Mass



Car C:
Large Mass

1. Car _____ would require the most work to lift.
2. Car _____ would require the least force to lift.
3. When car _____ is lifted to the top of the initial drop, it would have the most potential energy.

Car Lift Height Exploration

Looking Forward: what will happen if you change the height?!

You just learned about the relation between mass, work and energy. Now think about what will happen if you change the height of the car lift! What do you think will happen if you keep mass the same and change the height of the car lift? Can you make a hypothesis?

On Your Own: What will happen to work and energy when the height changes?

In order to identify the relationships between work, energy and height in your exploration, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

Make a Hypothesis:

If the height of the car lift increases, then the work required will **increase/ decrease/stay the same** (circle one) and the energy needed to lift the car will **increase/decrease/stay the same** (circle one).

Why do you think so?

_____

_____

_____

Let's Investigate Different Car Lift Heights!

Ready, Set, Explore!

You will now use a simulation to understand how the height of your car lift affects the work and energy required to start your ride.

Choose <u>one</u> of the car masses from your "Car Masses" exploration to input and keep constant in this simulation. Remember, your friction will be set to zero.

<u>Please note</u>: to maximize the machine performance and safety of the ride, the angle of the incline will remain constant in the simulation even though the height of the car lift will change.

Think Like Scientists and Engineers!

Scientists and engineers often conduct sets of related investigations to identify how different variables influence the results of their experiments.

My Car Lift Heights Data Chart

Car Mass (kg): _____

Trials	Lift Height (m)	Applied Force (N)	Work (J)	Potential Energy (J)
1	.2 m			
2	.4 m			
3	A height of your choice			

Report Out!

Think about the hypothesis you made about the height of the car lift and work and energy. Answer the following: My hypothesis was **confirmed / not confirmed** (circle one). Explain why, using specific information from your experiment data.

_____

_____

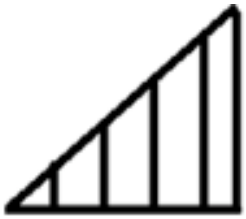
_____

Thinking about Roller Coaster Ramp Height

Now look at your data and the images below. What do the patterns in the data tell you about ramp height and its relationship to work, force and potential energy?

Ramp A: Short Height

Ramp B: Medium Height



Ramp C: Tall Height

1.Ramp _____ would require the most work.

2.When the car is lifted to the top of Ramp _____, it would have the most potential energy.

Looking Forward: What will happen if there is friction? Now that you learned about the relation between mass, height, work and energy, think about what will happen if we hold mass and height constant, but change the amount of friction on the roller coaster track!

On Your Own: What will happen to work and energy when the friction changes?

In order to identify the relationships between work, energy and friction in your exploration, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

Make a Hypothesis:

If the amount of friction between the car and the track increases, then the work required to lift the car will **increase/decrease/stay the same** (circle one) and the potential energy at the top of the initial drop will _____.

Why do you think so?

_____

_____

Let's Investigate Different Car Lift Surfaces!

Ready, Set, Explore! How can you help the Gonzales family keep the energy bills down? To make the most efficient design, your team needs to make decisions about the surface of the roller coaster track.

So far you have conducted all of your explorations without friction. However, in the real world there is always some friction. How will the amount of friction on different track surfaces affect applied force, work, energy, and efficiency in getting your roller coaster car to the top of your car lift?

Fill in the chart below by:

1. Using the same car mass as you did in your "Car Lift Heights" simulation
2. Choosing any height
3. Choosing three different levels of friction to test

Think Like Scientists and Engineers!

When conducting multiple, related investigations, scientists and engineers understand how important it is to:

- predict how changing one variable may affect the results of an experiment.
- control all other variables so generalizations can be made across several related experiments.
- set up data tables in order to see patterns and relationships between science concepts

My Car Lift Surfaces Data Chart

Lift Height ( ): _____
Car Mass ( ): _____

Trials	Level of Friction	Applied Force (N)	Work (J)	PE (J)	Efficiency (%)
1					
2					
3					

Thinking about Roller Coaster Track Surface

Report Out!

Think about the hypothesis you made about how the amount of friction between the car and the track would affect work and energy and answer the following: My hypothesis was confirmed / not confirmed (circle one). Explain why, using data from your experiment.

_____

_____

_____

_____

Now look at your data and the images below. What do the patterns in the data tell you about surface and its relationship to work, force and potential energy?

Surface A: Smooth Surface B: Medium Surface C: Very Rough

1. Surface _____ would require the most work.

2. When designing a ramp, selecting surface _____ would give you the greatest efficiency.

3. Force will be greatest with surface _____.

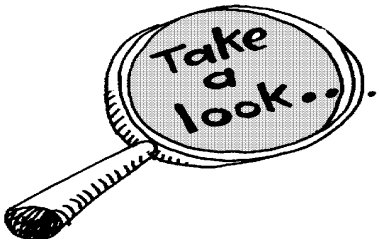
Reading Excursion #2

Ready, Set, Explore!

Let's put it all together! In your Car Lift Surface exploration, you collected data about how friction between the roller coaster car and the track relates to force, work and potential energy. How can you use this information to think about how to make your roller coaster more efficient? You and your team will explore the CoMPASS website, another physics website, and your textbook to learn more about the concept of efficiency and how it relates to other physics concepts in order to answer some questions about your roller coaster design.

www.compassproject.net

www.fi.edu/guide/hughes/energyconservation.html



Before doing your research, write down what you think the word "efficiency" means:

_____

_____

Now that you have conducted your research, explain the scientific meaning of the word efficiency:

_____

_____

In your Car Lift Surfaces exploration, look at the interesting pattern that you saw in the relationships between friction, force, work, potential energy (PE) and efficiency.

How does what you learned from your research about efficiency relate to the interesting energy pattern that you observed in your Car Lift Surfaces exploration?

_____

_____

What happened to the energy?

_____

_____

In reading different sources you should:

- evaluate their usefulness and how information fits with your existing ideas
- think about the credibility of the sources that you are reading, especially online resources
- discuss the science ideas you learned from all of the sources with your Dream Team to figure out the best way to answer the questions

What did we Learn from our Car Lift Explorations?

Report Out!

- Respond to the following questions in complete sentences.
- Take time to look back at all three of your virtual experiments and what you learned on CoMPASS to help you construct and express your scientific understandings below.
- Use evidence to support your thinking about these relationships

Now it's time for you to make the first decision about your roller coaster design! You need to make a decision about the height of your car lift and the mass of your car while thinking about how these decisions will affect the next section of your roller coaster ride. In order to help you make these decisions, first answer the following questions:

How will the combination of height and mass affect the potential energy at the top of the lift?

_____

_____

_____

What is the relationship between friction, work, and potential energy? Explain your thinking using data from your "Car Lift Surfaces" exploration and Reading Excursion #2 about efficiency.

_____

_____

_____

_____

Even though you don't know about the physics of the rest of the ride, what do you think the best combination of height and mass is at this point? Use your responses to the questions above to help you decide.

Car Mass_____ Car Lift Height _____

What did we Learn about Physics so Far?
Big Ideas Whole Class Discussion:

Have a whole class discussion about what you have learned from all of your experiments and reading excursions so far.

About Scientists and Engineers

The whole point of science is to construct theories that can explain how the world works. Theories are developed over a long period of time and are based on a great deal of data and evidence to support them.

While you will not construct scientific theories in science class, you will construct logical explanations to explain your current understanding of the science you are exploring.

Talk it out like scientists and engineers:

- communicate ideas clearly
- use data to support explanations
- evaluate others' ideas
- ask classmates for evidence to support their ideas
- think about how what you have learned will help in solving your overall challenge

Do you have any new questions? What else would you like to know or want to test?

Initial Drop Explorations

Ready, Set, Explore! In the last set of explorations, you learned how to get your roller coaster car safely to the top of the car lift in preparation for the initial drop. What do you think will happen when the car falls down the hill? In the next set of explorations, you will find out how a roller coaster car behaves while falling! The information you learn from these explorations will help to make the initial drop a real thrill!

You will conduct two Initial Drop explorations using a simulation and then you will be able to try your ideas out in the "real world" by setting up a physical experiment to help you to understand more about the following physics concepts and relationships:

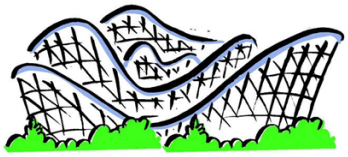
1. How the mass of the car affects work, energy, and velocity
2. How the height of the initial drop affects work, energy, and velocity
3. How the relationships you learned about mass, height, work, energy and velocity in the simulation compare to the relationships you observe about these physics concepts when trying your ideas out in the "real world" of your physical experiment

In your team, brainstorm some ideas about the best way to design your roller coaster's initial drop to maximize fun and keep things safe for your riders. What height of the initial drop as well as mass of the roller coaster car will help you to accomplish these goals? Write your ideas below and then share them with your teacher and the rest of the class in a whole class discussion.

Think Like Scientists and Engineers!

Scientists' and engineers' practices involve questioning, researching, planning investigations, making models, analyzing data, creating arguments, and sharing findings.

The process of doing science can involve many twists and turns because unexpected results can lead to new ideas and new investigations.



Hints and Tips:

- Think about your own experiences with falling objects.
- What are some key factors that you think affect how things fall?

Watch out Below! Initial Drop Explorations

Ready, Set, Explore! Read the statements below and write one of the following on the line provided before the statement: (Then, explain your thinking to your classmates.)

"A" if you Agree	"D" if you Disagree	"DK" if you Don't Know

Initial Drop Brain Warm Up!

1. _____ If an object with greater mass is released at the top of a hill, the object will move with a greater velocity as it goes to the bottom.
2. _____ The potential energy of an object at the top of a hill, is equal to the kinetic energy at the bottom.
3. _____ Objects that are released from the top of a hill will not be affected by friction as they move down.
4. _____ Without friction, an object's velocity at the bottom of the hill is determined by how steep the hill is.
5. _____ Without friction, if two objects, one with a high mass and the other with a lower mass, are released from the top of two different hills of the same height, they will both reach the bottom at the same time.
6. _____ Velocity and energy are not related.
7. _____ An object will gain more velocity when it is released from a higher hill than a lower one.
8. _____ Two objects of different masses (one less and one more) moving with the same velocity will also have the same amount of kinetic energy.
9. _____ Gravity is the force that makes objects fall.
10. _____ A falling object's acceleration is determined by its starting height.

How's your brain feeling? What questions are floating around in there? Make sure to catch your thoughts by writing them down!

Watch Out Below! Initial Drop Questions

One of the most exciting parts of a roller coaster ride is the initial drop. What makes the initial drop so exciting? Is it exciting because of rider anticipation for the rest of the ride, or is there some science behind making it fun, but also safe?

The Gonzales family wants the ride to be fun, safe, and efficient. Your job as scientists will be to find out how the initial drop height and roller coaster car mass will help to make your ride a success!

Collaborate with your team to construct some relevant questions that you may find answers to on CoMPASS and write them below.

Think Like Scientists and Engineers!

When scientists start a new, but related, exploration, they review data that they have already gathered and think about what they already know. This helps them to identify gaps in their knowledge that they still need to explore.

Hints and Tips:

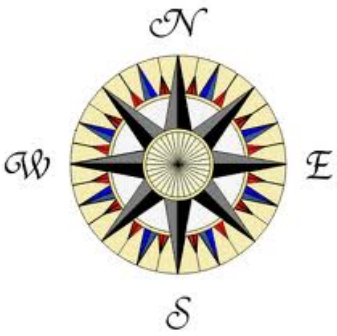
Think about:

- what you have learned about work, energy, forces, and motion.
- the science concepts you still need to learn to successfully complete the challenge
- asking questions that start with "how" or "why"
- discussing ideas with your group

Let's Find out more on CoMPASS!

Which direction will you go on CoMPASS?

Exploring the text and concept maps on CoMPASS will help you learn more about physics for your Watch Out Below! Initial Drop set of explorations and help you to solve your overall challenge. Take notes in your own words in the space provided below and on the following page.



Hints and Tips:

Think about:

- using your questions to help you decide what to read
- the concepts that you need to revisit and learn more about
- using the maps in CoMPASS to help you learn and explore important science concepts
- writing notes in your own words, NOT copying text from CoMPASS
- discussing ideas with your group

Initial Drop! Hypotheses about Height and Energy

Now that you learned some of the physics related to work and energy during your Car Lift exploration and the Initial drop activities so far, use what you know to help you to make hypotheses about what will happen during the initial drop.

On your own: Read and think about the variables in the statements below and make an ***if … then hypothesis*** statement about what you think might happen.

In order to identify the relationships between height, velocity and energy in your exploration, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

Hypothesis 1:

What will happen to the velocity of the roller coaster car at the bottom of the drop if the height of the initial drop changes?

If the height of the initial drop increases, then the velocity of the roller coaster car at the bottom _____

_____.

Hypothesis 2:

How will the amount of potential energy at the top of the initial drop be related to the amount of kinetic energy the car has at the bottom?

If the potential energy of the car at the top of the initial drop is greater, then the kinetic energy of the roller coaster car at the bottom of the drop will be

_____.

Why do you think this?

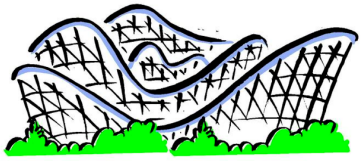
_____

_____

In your team: Discuss each team member's hypotheses and write group hypotheses about the height, velocity, work and energy in relation to the initial drop.

Initial Drop! Height Exploration

Ready, Set, Explore! Going fast on a roller can be a lot of fun, but going too fast might be unsafe. How do you think the height of the initial drop will affect the velocity of the roller coaster car? While it would be fun to test out different drops by riding roller coasters, it would be impractical and expensive!



Use a virtual model of a roller coaster to test ideas and learn more about physics. You can experiment with different initial drop heights to see how the roller coaster car's velocity is affected.

Please Note: the angle of the initial drop will remain constant in the simulation even though the height of the drop will change.

After your teacher demonstrates how to use the simulation, you will:

1. Based on what you learned about how the combination of height and mass affects potential energy, select four different release heights to test and one mass for your car (don't forget to label the units).

2. Use the chart on the next page to carefully record the information about:
   - height, velocity, potential energy, kinetic energy, and total energy at both the top and the bottom of the initial drop

3. Make sure friction is set to zero.

Think Like Scientists and Engineers! *Understand the pros and cons of using virtual experiments:*

Possible Pros:

- they allow exploration of things that can't be explored in the real world
- they provide us with different kinds of scientific information

Possible Cons:

- they do not do all the work for us – we need to think about the information they provide
- they are made by human beings and are not perfect
- models are judged by how well the data they provide matches the real world

Hints and Tips: As you set up and conduct your next simulation experiment, think about:

- how you can systematically change variables and set up your data chart to help you to see patterns and identify relationships between the variables

Let's Investigate Different Initial Drop! Heights

Car Mass ( ): _____		Trial 1	Trial 2	Trial 3	Trial 4
At the top of the Initial Drop	Drop Height (m)				
	Initial PE (J)				
	Initial KE (J)				
	Total Initial Energy (J)				
At the bottom of the Initial Drop	Final Velocity (m/s)				
	Final PE (J)				
	Final KE (J)				
	Total Final Energy (J)				

What do you notice about the distance the car travelled after the end of the drop?

_____

_____

Why do you think this is happening?

_____

_____

_____

_____

Thinking About Initial Drop! Heights

Report Out!

What was your hypothesis about height and velocity? Take a look at it and answer the following:

My hypothesis was **confirmed / not confirmed** (circle one).
Explain why, using specific information from your experiment data.

_____

_____

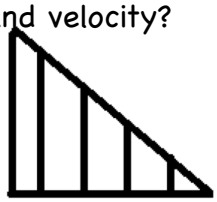
_____

_____

Now look at your data and the images below. What do the patterns in the data tell you about ramp height and its relationship to energy and velocity?

Drop A: Short Height

Drop B: Medium Height



Drop C: Tall Height

1. A car going down Drop _____ would have the most velocity at the bottom.

What is it about this ramp that causes the car to have the most velocity at the bottom?

_____

_____

_____

2. A car going down Drop _____ would have the most kinetic energy at the bottom.

3. Acceleration is a change in velocity over time. Looking at your chart, do you think that the car is accelerating as it goes down the drop? Why or why not?

_____

_____

_____

Initial Drop! Mass Exploration

Looking Forward: How will the mass of your roller coaster car affect your ride?!

Now that you learned the relationships between the height of the initial drop and its affect on velocity and energy, think about about how the mass of the roller coaster car will affect the ride. What do you think will happen if you keep the height of the initial drop the same and change the mass of the roller coaster car? Make some hypotheses below.

In order to identify the relationships between mass, velocity and energy in your exploration, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

Make your Hypotheses:

1. If the mass of the roller coaster car increases, then the velocity of the car will

_____.

Why do you think this?

_____

_____

_____

2. If the mass of the roller coaster car increases, then the amount of potential energy at the top of the initial drop will _____ and kinetic energy at the bottom will _____.

3. If the mass of the roller coaster car increases, then the amount of total energy at the top of the initial drop will be _____ the total energy at the bottom.

Let's Investigate Initial Drop! Mass

Ready, Set, Explore! Roller coaster cars can carry different numbers of people and can be made of different materials, which affects mass. Do you think that the mass of the roller coaster car will affect how fast the car goes? In this exploration, you will test how the mass of a roller coaster car affects its velocity in a virtual simulation.

Go back to the simulation and repeat your last experiment, but this time:

- select one height from your previous data chart and test it with four different masses for the car.
- use the chart to carefully record your new data.

Hints and Tips:

Think about:

- the controlled variables in this experiment that may be different from the last
- the variable you are changing and how changing this variable will help you learn more about physics
- how you can set up your data table to see these patterns and relationships

Drop Height Selected_____		Trial 1	Trial 2	Trial 3	Trial 4
At the top of the Initial Drop					
At the bottom of the Initial Drop					

Thinking About Initial Drop! Mass

Report Out!

What was your hypothesis about mass and velocity? Take a look at it and answer the following: My hypothesis was **confirmed / not confirmed** (circle one). Explain why using specific information from your experiment data on the previous page.

_____

_____

_____

_____

Now look at your data and the images below and answer the questions. What do the patterns in the data tell you about car mass and its relationship to energy and velocity?

Car A:
Small Mass

Car B:
Large Mass

1. At the bottom of the same initial drop, Car A will have less / more / the same amount of (circle one) velocity as Car B.

2. At the bottom of the same initial drop, Car A will have less / more / the same amount of (circle one) kinetic energy as Car B.

Why do you think this relationship between mass, velocity and kinetic energy is happening?

_____

_____

_____

_____

Hands on Fun! Trying Out Our Design

In all of your explorations so far you have used a virtual model to investigate physics in roller coasters. Next, you will have a chance to test out your new physics knowledge in a hands-on situation. Based on your Initial Drop explorations so far, choose the best combination of the mass of the car and height of the initial drop for your overall roller coaster challenge.

Mass of the Car_____

Height of Initial Drop_____

Looking Forward: How do you think the relationships you have been learning about in the simulation with zero friction will be similar or different when testing them in the "real world?"

Make some predictions:

How do you think the relationships you have learned about between height, mass, energy and velocity will be affected by friction in your physical experiment?

_____

_____

_____

_____

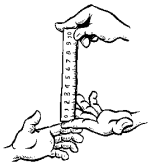
_____

_____

_____

_____

Hands On Fun With Roller Coasters – Part 1



Ready, Set, Explore!

Scientists and engineers use different types of models when they are doing investigations and designing projects. So far you have conducted five explorations using a simulation. While virtual models can be helpful in learning science, there are things you can learn from doing hands-on experiments. How do you think the science concepts you have learned so far will work in the real world?

- You now have a chance to use physical materials to test some of the physics ideas you have learned so far.
- Using the available materials – tracks, wood, glass, and steel balls – test out your initial drop ideas to help your solve the challenge. Make careful observations about what happens and take notes in the space below.

What we saw:

What we think:

_____

_____

_____

_____

_____

_____

_____

_____

_____

Hints and Tips:

- How can you use the supplies you have to make a track similar to the one you selected after using the simulation?
- How do the three balls you have to choose from relate to your decision about car mass?
- Thinking back to the simulation, do you notice anything different here about the motion of the ball after the drop?
- How is data collection different here than in the simulation? What are the benefits/ drawbacks?

Let's Talk About Hands on Fun with Roller Coasters – Part 1

Talk about your ideas!
Now that you have finished your Hands on Fun with Roller Coasters, have a conversation with your team about the following questions. Be prepared to share your ideas with the whole class!

- What are the big differences between using the simulation and doing a hands-on experiment? What are the advantages and disadvantages of each?

  For example, were you able to see differences in the motion of the ball when you changed the height of the drop or the mass of the ball during the hands-on experiment?

- In the simulation and in the hands-on experiment you are limited in how high you can make your roller coaster. How do you think engineers use models like these help them design and build the real thing?

- In your simulation explorations with zero friction, you may have noticed that the roller coaster car continues without stopping (as indicated by the increasing distance output). Was this the case in your Hands on Fun with Roller Coasters? Did your ball go on forever? Think about the forces that may have caused your ball to stop.

- Has this hands-on experiment caused you to think differently about your initial drop height or car mass choices?

Reading Excursion #3

Ready, Set, Explore!

In your car lift and initial drop explorations you recorded data from the simulation about potential and kinetic energy. You may have noticed some patterns in this data both with and without friction.

Details for your excursion! You and your team will explore the CoMPASS website, the other physics website listed below, and your textbook to learn more about the patterns that you have been seeing in your data and the Law of Conservation of Energy.

www.compassproject.net

www.iptv.org/exploremore/energy/Energy_In_Depth/sections/potential.cfm

What does the word conservation mean to you?

_____

_____

Based on what you read, what does the Law of Conservation of Energy mean?

_____

_____

_____

_____

Think Like Scientists and Engineers!

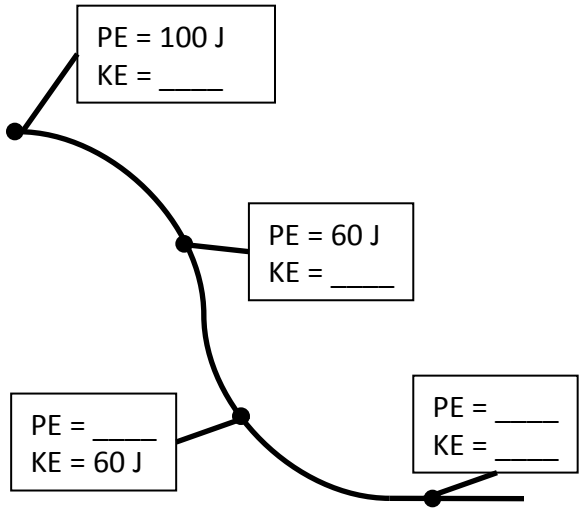
Remember that scientists and engineers often use different sources of information in order to learn about concepts that are important to their research.

In order to do investigations and create designs, we need to understand the scientific meaning of important concepts.

Reading Excursion #3

Discuss with your Team! How do you think the Law of Conservation of Energy applies to your rollercoaster design? What types of energy are related to your roller coaster design?

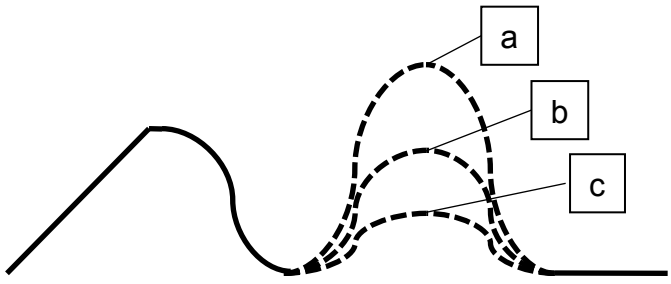
Use what you have learned about the Law of Conservation of Energy to fill in the blanks below on a drop ***with no friction.***



How would the situation above be different if there was friction on the drop?

_____

_____



Thinking about the Law of Conservation of Energy, which of the hills above (a, b, or c) would not work if the initial drop of the rollercoaster is the height shown? Why?

_____

_____

_____

What did we Learn in the Initial Drop! Exploration?

Report Out!

- Take time to look back at all three of your virtual experiments and what you learned on CoMPASS to help you construct and express your scientific understandings below.
- Use evidence to support your thinking about these relationships.

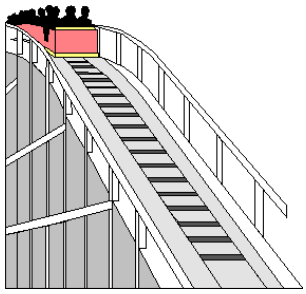
Think like Scientists and Engineers!

ALWAYS use data as evidence to support your thinking!

Based on your Initial Drop explorations, choose the best combination of the mass of the car and height of the initial drop for your overall roller coaster challenge.

Mass of the Car_____

Height of Initial Drop_____



Use appropriate data from any of your experiments so far to explain your choices. Make sure to discuss the relationships between:

- mass and velocity
- PE, height and velocity
- PE and KE at the top and bottom of the drop

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Hints and Tips:
Looking back at your data:

What do you notice about the relationship between:

- height and velocity
- initial potential energy and final kinetic energy
- mass and velocity
- mass and energy
- friction and velocity
- friction and energy

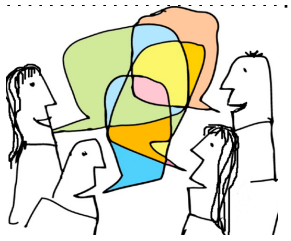
What did we Learn about Work, Energy, and Physics so Far?
Big Ideas Whole Class Discussion:

Report Out! Discuss your findings with your classmates and teacher. Use the space below to take important notes.

Think Like scientists and engineers!

Constructing scientific theories (the main goal of science) takes a long time and a lot of evidence.

- While you will not be able to develop theories in class, you will use data to create logical explanations about physics.



Hints and Tips!

- communicate your ideas using data to support your explanations
- ask your classmates for evidence that supports their ideas
- think about how the information you learn might help you to solve your challenge

Do you have any new questions? What else would you like to know or want to test?

Our Roller Coaster Ideas Check-In

Use the space below to create a labeled diagram of your ideas for your roller coaster so far.

Label the different sections of your roller coaster. Then, do your best to identify the forces acting on the riders and the energy changes in those sections.

Remember at a minimum your roller coaster must include the following:

- A way to lift your car to the initial drop
- An initial drop
- A hill
- A flat section long enough to stop the roller coaster car

Explain, using science terms where possible, how your coaster will work and how it is exciting, safe and efficient. Use information from all of your explorations and reading excursions so far to support your choices.

Reading Excursion #4

Ready, Set, Explore! While your roller coaster car is going over a hill or stopping, Newton's Laws of Motion can be used to determine how to keep riders safe and make sure that the ride gives them a thrill. How can understanding Newton's Laws help you to design a fun and safe hill and help you to stop the car safely?

Details for your excursion! You and your team will explore the CoMPASS website, the other physics websites listed below and your textbook to learn more about Newton's Laws and how they will help you to design a hill and a way to safely stop your roller coaster car.

www.compassproject.net

www.physics4kids.com/files/motion_laws.html

www.beyondbooks.com/psc91/4d.asp

Think Like Scientists and Engineers!

Scientists and engineers often use different sources of information to learn about concepts that are important to their research.

As you go on this excursion, think about:

- why Newton's Laws are important to understand to make your ride both fun and safe
- how the physics of roller coasters helps you to make decisions about your design

Read about and take notes on Newton's Laws.

Newton's 1st Law: _____

_____

Newton's 2nd Law: _____

_____

Newton's 3rd Law:

_____

_____

It is important that you understand Newton's 1st and 2nd Laws in order to construct your roller coaster. With your team, discuss how these laws might help you with your roller coaster design.

Reading Excursion #4

With your Team! Now that you've had a chance to learn about Newton's Laws, use the information from CoMPASS, the other websites and your textbook to answer the following questions with your team. Thinking about these questions will help you to apply Newton's Laws to your roller coaster design.

Think Like Scientists and Engineers!

After reading about a new topic scientists often take time to study other examples of the topic before making decisions for their own work.

The image below shows a ball rolling with a constant speed on a surface without friction. Use what you have learned about Newton's 1st and 2nd Laws to answer the questions that follow.

1. How long will the ball continue at a constant velocity? Why?

2. If there were friction on the ground, what would be different? Why?

What is the formula for Newton's 2nd Law? _____

Use Newton's 2nd Law to find the amount of acceleration in the following examples:

If the cart has a mass of 10 kg and the man pushes with a force of 10 N, what will the acceleration be?

What if the mass of the cart is increased to 20 kg?

What if the force being used is increased to 20 N?

Looking at the examples, what can you say about the relationship between mass, force and acceleration?

In this example, the acceleration is a change in velocity by the cart going faster or slower. What other change can there be in velocity that would result in acceleration?

Our Hill Explorations!

Ready, Set, Explore! Have you ever ridden a roller coaster that has lots of hills? If you have, you know how thrilling it can be. However, the addition of a hill to a roller coaster requires understanding of some new physics ideas in order to have an exciting ride and still keep the riders safe. The Gonzales family learned that too much acceleration can be dangerous for riders because they undergo too much force, but if there is not enough acceleration the ride will not be fun.

To keep this ride safe, acceleration should not exceed 40 m/s^2, and to be sure it is exciting it should have at least one point where acceleration is above 10 m/s^2.

You will conduct two Hill explorations using the simulation and then you will be able to test your ideas with the hands-on materials. As you complete these investigations, you will learn more about the following:

1. How high the hill needs to be in relation to the initial drop in order for the ride to continue as well as be fun and safe.

2. How the shape of the hill affects the fun and safety of the ride.

Hill Brain Warm Up! In your team, brainstorm anything that you think you already know about the science behind roller coaster hills and write your ideas below. On the next page, you will brainstorm questions to research on CoMPASS.

What we think we know about the science behind designing roller coaster hills:

Think Like Scientists and Engineers!

Scientists and engineers write a lot of questions to guide their explorations.

Scientists and engineers think about what they want to test before they research.

Hints and Tips:

- Think about your experience riding roller coasters or other rides.
- Think about what you have learned about height and potential energy so far.
- Think about what you have learned about forces and how they might affect your ride.

What our group wants to learn about hills:

(Brainstorm with your team and write your questions below)

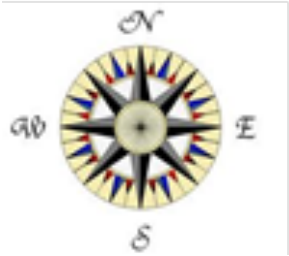
What we talked about as a class:

Hints and Tips:

You might want to think about how:

- forces are acting on your riders and how this may be related to acceleration
- hill height and car mass will affect the safety and excitement of your ride
- the Law of Conservation of Energy helps you to choose the appropriate hill height for your ride
- the constraints for fun and safety on the previous page affect your hill design
- major changes in velocity and acceleration will affect what your riders will experience
- the shape of the hill may affect the fun and safety of the roller coaster

Let's Find out More on CoMPASS!



Which direction will you go on CoMPASS?

Exploring the text and concept maps on CoMPASS will help you learn more about physics for your Hill Explorations and help you to solve your overall challenge.

- Use the CoMPASS website to help you learn about new science ideas.
- Take notes about what you learn in the space provided below.

Hints and Tips:

Think about:

- choosing to read concepts that will help you answer your questions and solve the challenge
- the science ideas that affect the experience of the riders in a roller coaster
- what forces riders experience in a roller coaster
- how using the maps in CoMPASS can help you learn
- writing notes in your own words, NOT copying text from CoMPASS
- discussing ideas with your group
- discussing how the information will help with your challenge

Thrilling and Safe Hill Exploration: Hill Height

Ready, Set, Explore! The Gonzales family wants at least one hill on their rollercoaster. In this exploration you will investigate the best height to use for your hill in order make the ride exciting and safe.

Based on what you have learned about acceleration and how exciting it can be, what hill height will be most fun for the riders?

Using what you know about the Law of Conservation of Energy, how tall do you think a hill can be compared to the initial drop?

Think Like an Engineer!

Engineers often have to work within design parameters – rules that they have to follow with their design. They must find the best design while still following these rules. They need to understand the underlying science to be able to do this.

On Your Own:

In order to identify the relationship between hill height and the acceleration of the car, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

Make your Hypotheses:

1. If the hill is too short compared to the initial drop, then the acceleration of the car will be…

_____

Why do you think so?

_____

_____

_____

Thrilling and Safe Hill Exploration: Hill Height

In order to identify the relationship between hill height and the initial drop, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

2. If the hill is taller than the initial drop, then the car will…

_____

_____

Using what you've learned about the Law of Conservation of Energy, why do you think this?

_____

_____

_____

Let's Investigate Hill Height

Using the simulation:

1. Use the chart below to set up your experiment and record data from the simulation.
2. Create a roller coaster with the initial drop height and roller coaster car mass you chose on page 49.
3. Add a hill after the end of the drop. Set your hill type to "round."
4. Test at least four different hill heights. Be sure that you test the following:
   - one hill larger than the initial drop
   - one hill the same height as the initial drop
   - one hill much smaller than the initial drop
   - one hill of a height that is in between the same height of the initial drop and the smaller height you chose
5. Decide where you will need to insert Flags in the simulation in order to get the values you need for the variables in your chart.

   *Please note, in the simulation the car is attached to the track. This means the track exerts an applied force on the car to keep it from flying off. This will not be the case in your physical experiment.

Think Like Scientists and Engineers!

All designs have constraints.

To keep this ride safe, acceleration should not exceed 40 m/s^2. This is because when acceleration exceeds this amount, the forces that the riders undergo are too great.

To be sure it is exciting it should have at least one point where acceleration is above 10 m/s^2.

Drop Height _____ Car Mass _____ Hill Shape Round

	Trial 1	Trial 2	Trial 3	Trial 4
Hill Height				
PE at Hill Top				
KE at Hill Top				
KE at Hill Base				
Velocity at Hill Top				
Maximum Acceleration				
Maximum Net force				

Thinking About Hill Height

Report Out!

What was your hypothesis about how hill height affects acceleration?

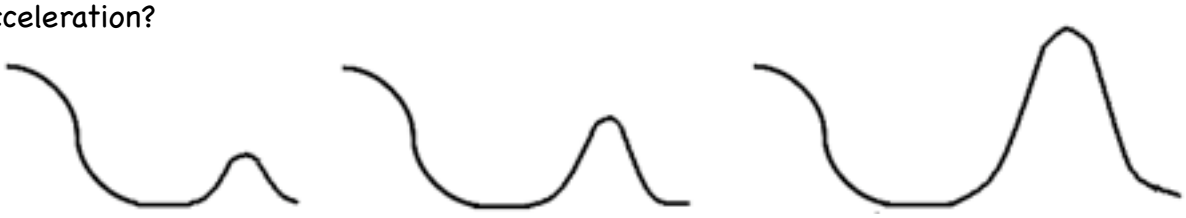
My hypothesis was confirmed / not confirmed (circle one).
Explain why, using specific information from your experiment data.

_____

_____

_____

Now look at your data and the images below. What do the patterns in the data tell you about the initial drop height and its relationship to energy, velocity and acceleration?



Hill A Hill B Hill C

1.Hill _____ would not work because

_____.

2. Hill _____ would be unsafe because

_____.

3. What is the relationship between the amount of velocity at the top of the hill and the amount of net force? How does this relate to Newton's Second law? (hint: how are velocity and acceleration connected)?

_____

_____

_____

4. After completing this exploration, our hill height will be_____.

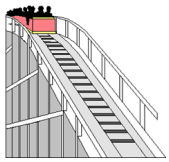
Thrilling and Safe Hill Exploration: Hill Shape

Ready, Set, Explore! The Gonzales family wants at least one hill on their rollercoaster. In the last exploration you learned how the hill height in relation to the initial drop affects force and acceleration. You also learned how forces cause acceleration, which impacts both the safety and the excitement that the riders experience during the roller coaster ride.

In this exploration you will investigate the best shape to use for your hill in order make the ride exciting and safe. You will test three different roller coaster hill shapes (Gradual, Round and Steep) to see how they affect force and acceleration.

Remember, to keep this ride safe, acceleration should not exceed 40 m/s^2. This is because when acceleration exceeds this amount, the forces that the riders undergo are too great. However, to be sure it is exciting it should have at least one point where acceleration is above 10 m/s^2.

In order to identify the best shape for your hill, what aspects of your roller coaster need to change and what needs to stay constant?



Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

Make your Hypotheses:

1. Write your own hypothesis about which hill shape will be the best choice for a safe and fun ride (Gradual, Round or Steep).

_____

_____

Why do you think that this shape will be safe and exciting?

_____

_____

_____

Let's Investigate Hill Shape

Before using the simulation for this exploration, you will need to think about the data you want to collect in order to test your hypothesis.

Completing the Data Chart:

•Think about the variables you must control and your manipulated variable. You should also identify the variables you want to measure that may change as a result of your manipulated variable.

•Look back at the chart from your Hill Height Exploration to help you decide how to place these variables in your data chart below.

•Remember to use the initial drop height, car mass and hill height from your previous "Hill Height" investigation to test out different hill shapes.

Think Like Scientists and Engineers:

Scientists and engineers use previous work to help them determine what data is important to collect during investigations.

Drop Height _____ Car Mass _____ Hill Height _____

	Trial 1	Trial 2	Trial 3	

Thinking About Hill Shape

Report Out!

What was your hypothesis about hill shape? My hypothesis was confirmed / not confirmed (circle one).

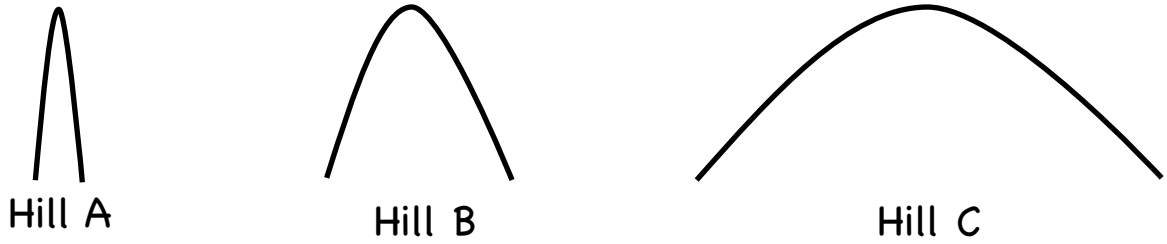
Explain why, using specific information from your last experiment.

_____

_____

_____

Now look at your data and the images below. What do the patterns in the data tell you about hill shape and its relationship to force and acceleration?



Hill A Hill B Hill C

1. Riders in a car going over Hill _____ would experience the highest acceleration.

What is it about the shape of this hill that causes riders to experience more acceleration than the others? Support your ideas with evidence from your exploration and reading excursion.

_____

_____

_____

_____

2. A car going over Hill _____ will experience the most net force.

What is it about the shape of this hill that causes the car to experience more net force than the others? Support your ideas with evidence from your exploration and reading excursion.

_____

_____

_____

_____

What did we Learn in our Hill Explorations?

In the hill explorations you explored how hill height and shape affected the velocity, acceleration and net force that the riders experienced. Now you can choose the combination of the hill height and shape that will keep your riders safe but also allow them to have fun.

When making your decisions below, think about:

•the initial drop height and car mass you chose during your previous explorations

•data from your hill explorations

•information about Newton's 2nd law from your reading excursion

Car Mass_____

Initial Drop Height_____

Hill Height_____

Hill Shape_____

Use appropriate data from any of your experiments so far to explain your choices.

Make sure to discuss the relationships between:

•velocity, acceleration and net force and how this relates to Newton's 2nd Law

•PE at the top of the initial drop and hill height

_____

_____

_____

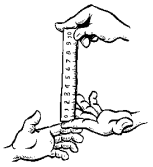
_____

Thought Question! How do you think your hill height and shape choices would change if either the initial drop height or car mass changed? Discuss this with your team.

Looking forward! Now you are going to have a chance to try out some of your ideas in a hands-on investigation! Below are some things to think about as you do this activity.

Thinking about your hill, what are the forces that are acting on the roller coaster car and its riders? Based on Newton's 1st Law, what would happen to the car if it was not attached to the track? Discuss this with your team.

Hands On Fun With Roller Coasters – Part 2



Ready, Set, Explore! Scientists and engineers use different types of models when they are doing investigations and designing projects. You have conducted many simulation experiments throughout this unit. These models can be helpful in learning science. However, there are things you can learn from doing hands-on experiments too. How does the science you have learned so far work in the real world?

- Using the available materials – tracks, wood, glass, and steel balls – create a physical model of your roller coaster design so far to test out your hill height and shape ideas:
    - Try several different heights and shapes.
    - If you have time, try out multiple hills
- Make careful observations about what happens and take notes in the space below.

What we saw:

What we think:

_____

_____

_____

_____

_____

_____

_____

_____

_____

Hints and Tips:

- How can you use the supplies you have to create an accurate model of your roller coaster design so far?
- How do the three balls you have to choose from relate to your decision about car mass?
- Thinking back to the simulation, do you notice anything different about the motion of the ball as it goes over the hills? What may account for any differences?
- How is data collection different here than in the simulation? What are the benefits/ drawbacks?

Let's Talk About Hands on Fun with Roller Coasters – Part 2

Talk about your ideas!

Now that you have finished your Hands on Fun with Roller Coasters, have a conversation with your team about the following questions. Be prepared to share your ideas with the whole class!

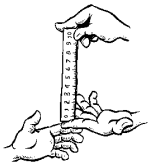
What are the big differences you notice between using the simulation and doing a hands-on experiment? What are the advantages and disadvantages of each?

Did the hill you designed in the simulation work in the hands-on experiment? What are some factors that might make the outcome different?

Your design only requires one hill. Did you have time to experiment with more than one hill? What observations do you have about how your design challenge changes when you have multiple hills?

After trying out your ideas in this hands-on experiment, do you want to make any changes to the initial drop height, car mass, or hill height you selected? Why or why not?

Optional Hands On Fun With Roller Coasters



Ready, Set, Explore!

Even though the Gonzalez family has not asked for a roller coaster that has a loop, if you have finished exploring the hill in your hands-on exploration and have extra time, you can have some fun trying out a loop! Before trying out a loop, think about the physics you have learned about roller coasters and make informed decisions about what height and shape the loop should be in order to keep the ride safe and fun.

For example you might want to think about:

- the Law of Conservation of Energy and how loop height might relate to the initial drop height
- Newton's Laws
- How loop height and shape affects force and acceleration

Make careful observations about what happens and take notes in the space below.

What we saw:

What we think:

Let's Talk About Optional Hands on Fun with Roller Coasters

Talk about your ideas!

Now that you have finished your Hands on Fun with Roller Coasters, have a conversation with your team about the following questions. Be prepared to share your ideas with the whole class!

What similarities and differences do you see in how the hill works and how a loop works?

Thinking about the different loops you tried, what can you say about loops that work and loops that don't? Using what you have learned about science, why do you think this is?

What did we Learn about Physics so Far?
Big Ideas Whole Class Discussion:

Report Out! Discuss your findings with your classmates and teacher. Use the space below to take important notes.

Hints and Tips!

- communicate your ideas using data to support your explanations
- ask your classmates for evidence to support their ideas
- think about how the information you learn might help you to solve your challenge

Do you have any new questions? What else would you like to know or want to test?

Our Roller Coaster Ideas Check-In

Use the space below to create a labeled diagram of your ideas for your roller coaster so far.

Label the different sections of your roller coaster. Then, do your best to identify the forces acting on the riders and the energy changes in those sections.

Remember at a minimum your roller coaster must include the following:

- A way to lift your car to the initial drop
- An initial drop
- A hill
- A flat section long enough to stop the roller coaster car

Explain, using science terms where possible, how your coaster will work and how it is exciting, safe and efficient. Use information from all of your explorations and reading excursions so far to support your choices.

Stop That Car! Exploration

Ready, Set, Explore! Now that you have made many decisions about your roller coaster design for the Gonzales family, you need to decide how you will stop the ride. The Gonzales family wants to stop their roller coaster car safely and effectively.

The car can be stopped quickly using a braking system. However, stopping too quickly is unsafe. The Gonzales family can increase the distance the car travels on the track before it comes to a stop. But, this can be expensive. So, they need to find an effective balance between the stopping distance needed and a safe and effective braking system.

How can what you've learned about physics so far help you to figure out the best way to stop the car? What effect will friction have on stopping the car and how can this be done safely?

In this exploration you will learn about physics concepts that will help you to understand the roles that force, mass, height, velocity, acceleration, Newton's Laws, and the Law of Conservation of Energy play in this design task.

Using the box below, brainstorm with your team some things that you will need to know in order to stop the car so that the passengers are safe and the roller coaster is not too costly. Write your ideas below and then share them with your teacher and the rest of the class in a whole class discussion.

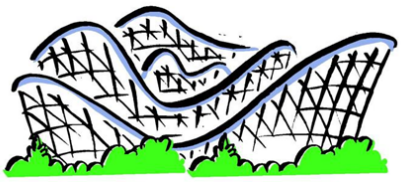
Brainstorming Box

Hints and Tips:

- Think about what you have learned about changing the velocity of your roller coaster car.
- What are some ways that you can use what you already know to design a method to stop your car safely?

Stop That Car! Questions

Use the area below to write down the things you and your group would like to research on CoMPASS before starting this exploration.



Hints and Tips:

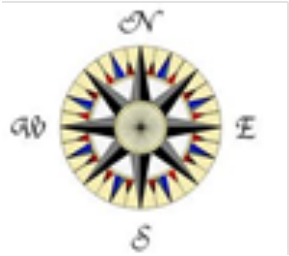
•Take a moment to look back at the reading you did about forces. What force acts against the direction of motion?

•What do you know about how to keep riders safe? What limits does your roller coaster need to have? Remember, acceleration greater than 40 m/s^2 is not safe for riders.

•Think about how long the stop area of your ride needs to be.

Our Team Questions:

Let's Find out More on CoMPASS!



Which direction will you go on CoMPASS?

Exploring the text and concept maps on CoMPASS will help you learn more about physics for the Stop the Car Exploration and help you to solve your overall challenge.

- Use the CoMPASS website to help you learn about new science ideas.
- Take notes about what you learn in the space provided below.

Hints and Tips:

- Read concepts that will help you answer your questions and solve the challenge.
- Use the features in CoMPASS to help you make good decisions about what to read.
- Take notes in your own words.
- Talk with your team about the science you are learning. This will help you to better understand the science behind roller coasters to create a successful design.

Stop That Car! Exploration: Friction

In making this hypothesis, you need to think about a safe way to stop the roller coaster car. You will want to consider the following:

- How can Newton's 1st law inform your decision about stopping the car?
- What can Newton's 2nd law tell you about keeping your riders safe while the car stops?
- What limits do you need to consider in terms of force, acceleration and track length when stopping the car?

On your Own:

In order to identify the relationship between friction in the breaking system and the acceleration of the car, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

Make a hypothesis:

1. Using the information you have learned about physics so far, think about how the amount of friction in the braking system at the end of the ride will affect the amount of force and acceleration the riders will experience as the car is stopping.

_____

_____

Why do you think this?

_____

_____

_____

Hints and Tips:

Look back at your previous hypotheses to help you write your ideas in an if/then format.

Think about which variables you are testing and what you think you will find.

Let's Investigate Friction to Stop That Car!

Ready, Set, Explore! Based on your current roller coaster design, use the simulation to add a section of track to stop the car. Experiment with different levels of friction in the braking system to find a way to stop the car that is safe and will not cost too much or take up too much space in the park.

You will need to create your own data chart for this exploration.

- In the box below, generate a list of variables that will be important for this experiment.
- Think about where to place these variables (in columns, rows or outside of the chart).
- Think about how you can organize the variables in your chart and the increments of your manipulated variable to help you see patterns in the data.
- Use your current design information from page 66 to set up your experiment.

Variable that we are manipulating: Friction

Variable(s) that we think changing friction will affect (Look back at your hypothesis!):

Variable(s) we will keep constant in our exploration:

Let's talk About Friction to Stop That Car!

Report Out!

1. Look back at your hypothesis about the amount of friction in the braking system and its effect on the force and acceleration your riders will experience. My hypothesis was confirmed / not confirmed (circle one).

Explain why using specific information from your experiment data.

_____

_____

_____

_____

2. Our current selections for our roller coaster are: (Information for letters a - d should be the same as the information on page 66 after your hill exploration.)

a) Car Mass_____
b) Initial Drop Height:_____
c) Hill Height: _____
d) Hill Shape: _____
e) Level of Friction_____
f) Length of Track Needed to Stop the Car_____

3. Explain your choice for the level of friction above. Use Newton's 1st and 2nd Laws and data from your experiment to support your reasoning.

_____

_____

Looking Forward! You are very close to having your final design!! However, before submitting a final design proposal for any job, engineers always take time to make sure that they have the best design possible. While your design may be good so far, can you make it better?

Discuss with your Team - How might changing your initial drop height and car mass affect the amount of friction or length of track needed to stop the car?

Stop That Car! Exploration: Mass and Height

In your previous exploration you saw how a friction breaking system can be used to stop the car, and you were able to make decisions about the level of friction your braking system will need and the length of track needed to stop the car safely.

However, the Gonzalez family would like you to go back and look at other parts of your design to see if there is a way to further reduce the amount of track used and the amount of force and acceleration riders experience when stopping. For this exploration, you will reevaluate the choices you have made about car mass and initial drop height, and will use the simulation to experiment with how different car masses and initial drop heights affect stopping distance, force and acceleration.

With your team!

Solving this part of the challenge will require you to make connections between several physics ideas that you have learned so far. With your team, write down what you know about the following physics ideas

Velocity and Acceleration:

_____

_____

_____

Newton's 2nd Law:

_____

_____

_____

The Law of Conservation of Energy:

_____

_____

_____

Kinetic Energy:

_____

_____

_____

Hints and Tips:

Think about places in your scientists notebook where you have written down information about these physics ideas.

If you don't have information about these ideas written down, where else might you be able to look?

Stop That Car! Exploration: Mass and Height

In making this hypothesis, you need to think about how the different parts of the roller coaster affect each other.

You will want to consider the following:

- How Newton's 2nd Law can give you information about the how the car's mass might affect the amount of force needed to stop it.
- How force, acceleration and velocity are related and how they affect the distance it takes for a car to stop.
- How the Law of Conservation of Energy can inform your understanding of roller coaster velocity to help you determine the best height of the initial drop and the stopping distance for the car.

On your Own:

In order to identify the relationship between car mass and force, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

Make a hypothesis:

1. Write a hypothesis about how the mass of the car will affect the amount of force needed to stop it.

_____

_____

_____

Why do you think this?

_____

_____

Stop That Car! Exploration: Mass and Height

In order to identify the relationship between drop height and stopping distance, what aspects of your roller coaster need to change and what needs to stay constant?

Variable that needs to change (manipulated variable):

_____

Variable(s) that must remain constant (controlled variables):

_____

_____

Make a hypothesis:

2. Write a hypothesis about how the height of the initial drop will affect the distance it takes to stop the car.

_____

_____

_____

Why do you think this?

_____

_____

_____

Let's Investigate Stop That Car!: Mass and Height

Now that you have had a chance to think about the relationships between the physics concepts, test out your hypotheses using the simulation. As you work, think about what you have learned during other explorations in relation to recording data in ways that help you to see patterns.

Using the simulation:

1. For your first trial, use your current design decisions on page 80 as inputs in the simulation.
2. Do three trials with initial drop height as the variable you change.
3. Do three trials with car mass as the variable you change.
4. Use the chart below to record your data as you go.

Drop Height	Car Mass	PE at top of Drop	KE at end of hill	Velocity at end of hill	Stop Dist.	Net Force in stop area	Accel. in stop area
Trial using current design decisions							
Three trials testing initial drop height as a variable							
Three trials testing car mass as a variable							

What patterns do you see in the data? Do initial drop height and car mass have an effect on how your car stops? Do you want to make changes to your design choices? If you do want to make changes, take some time before leaving the simulation to be sure your hill is still safe and fun with your new initial drop height and/or car mass.

Let's talk About Mass and Height to Stop That Car!

Report Out!

1. Look back at your hypotheses about how initial drop height and car mass will affect how the car stops. My hypotheses were confirmed / not confirmed (circle one).

Explain why using specific information from your experiment data.

_____

_____

_____

_____

2. How did changing car mass affect the stopping of the car? Use your understanding of Newton's 2nd Law and data from your experiment to explain why this happened.

_____

_____

_____

3. How did changing initial drop height affect the stopping of the car? Use your understanding of the Law of Conservation of Energy and its effect on velocity as well as data from your experiment to explain why this happened.

_____

_____

_____

4. Our current selections for our roller coaster are: (If you chose not to make changes to your selection for initial drop height or car mass, these will be the same as page 80.)

a) Car Mass_____
b) Initial Drop Height:_____
c) Hill Height: _____
d) Hill Shape: _____
e) Level of Friction_____
f) Length of Track Needed to Stop the Car_____

Stop That Car! Whole Class Discussion

Team Brainstorm! Look at the data for your design. What science ideas are important in explaining why this design worked and others didn't? Be prepared to justify your design to the class using big science ideas. Write some of these ideas below.

Think Like Scientists and Engineers!

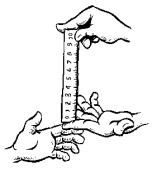
Constructing scientific theories (the main goal of science) takes a long time and a lot of evidence. While you will not be able to develop theories in class, you will use data to create logical explanations about physics.

Report Out! Discuss your findings with your classmates and teacher. Use the space below to take important notes.

Hints and Tips!

- Communicate your ideas using data to support your explanations.
- Ask your classmates for evidence to support their ideas.
- Think about how the information you learn might help you to solve your challenge.

Hands On Fun With Roller Coasters – Final Design



Ready, Set, Explore!

Use the hands on materials to set up and test your final design. Pay attention to whether it works and any differences between the simulation and the real world and record your observations below.

Once you have tested your final design, use the supplies to experiment and create some "just for fun" roller coaster configurations. Try adding extra sections like hills, loops, turns, and flat sections. Sketch the roller coaster designs you create in the space below, and take notes about what worked and what didn't.

Notes about our final design:

_____

_____

_____

_____

_____

Sketches for our "just for fun" roller coaster ideas:

Hands on Fun with Roller Coasters – Final Design

Talk about your ideas!

Now that you have finished your Hands on Fun with Roller Coasters, have a conversation with your team about the following questions. Be prepared to share your ideas with the whole class!

What are the big differences you notice between using the simulation and doing a hands-on experiment? What are the advantages and disadvantages of each?

Thinking about the "just for fun" designs you created, what other physics concepts would you need to learn more about in order to make designs like this work?

Big Ideas Whole Class Discussion

Your Final Roller Coaster Design Proposal!

If your remember, the Gonzales family put out a call for local scientists and engineers to submit proposals for a fun, safe, and efficient roller coaster that they should add to their park to increase park attendance. You had the opportunity to conduct several physics explorations to help you to learn the science behind roller coasters and provide you with evidence to support the choices you make in your final roller coaster design.

Make a labeled diagram, label your engineer proofs and write a letter to the Gonzalez family that explains your roller coaster design and why it is fun, safe and efficient.

Think Like an Engineer!

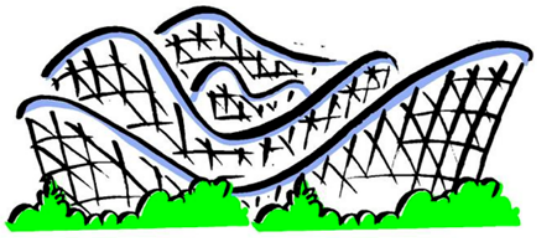
Engineers use information they have gathered from all of their investigations to support their design decisions.

They clearly communicate their ideas in many ways, including drawings and writing.

Hints and Tips:

Your proposal will be more convincing if you:

- Explain the science behind your decisions by elaborating the science concepts:
    - behind how each section of the roller coaster works
    - that make your roller coaster exciting
    - behind what makes your design safe
    - about how your roller coaster design is efficient
    - behind your choice of roller coaster car mass
- Provide data from your experiments and information from your other research sources (such as CoMPASS) as support, or evidence, for your proposal choices.



Your Final Roller Coaster Design Proposal Diagram!

Your roller coaster should include information you learned from all of your explorations. At a minimum your roller coaster design must include:

- A way to lift your car to the initial drop
- An initial drop
- One hill
- A flat section long enough to stop the cars

Label and identify the following on your diagram below:

- Each force acting on the people during the ride and its direction
- Energy changes that occur during the ride

Your Labeled Roller Coaster Diagram:

Your Final Roller Coaster Engineer Proofs

Engineers use proofs to give detailed information about different parts of their design. Below you will find a proof for each section of your ride. On each one label the following:

• The dimensions of your ride. This means you need to label height, length and shape of the sections where applicable.

• The potential, kinetic and heat energy, where applicable, at each point marked with a black dot using data from all of your explorations

• The forces acting on the roller coaster car at each point where a block is drawn

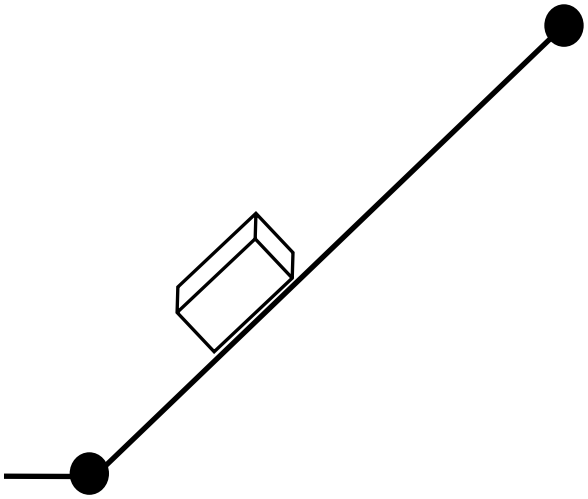
Use the "notes" area to the right of each of the proofs to write down ideas and data related to how your design for that section of the roller coaster is:

•Fun and safe

•Efficient (if applicable)

Refer back to your data charts as you work on labeling your proofs and jotting down notes. If you have made changes to your design, if possible, go back to the simulation to get values for the items you need to label.

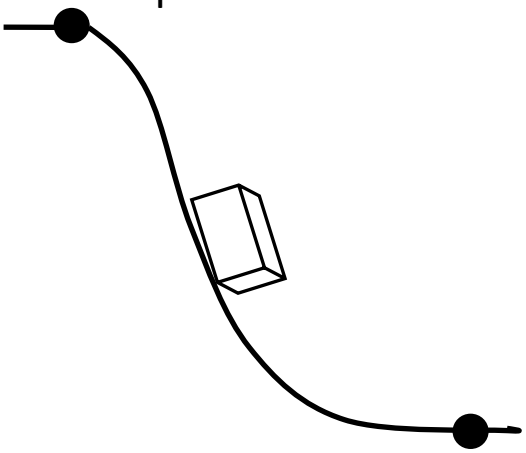
Car Lift:



Car Lift Notes:

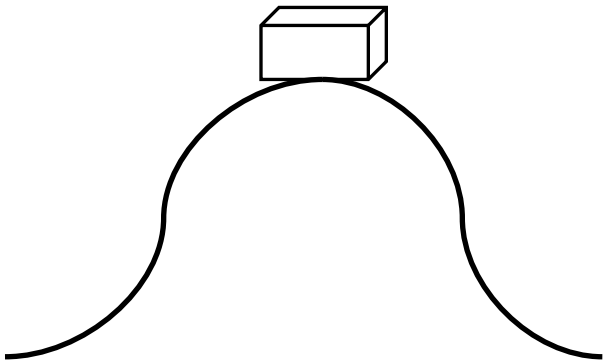
Your Final Roller Coaster Engineer Proofs

Initial Drop:



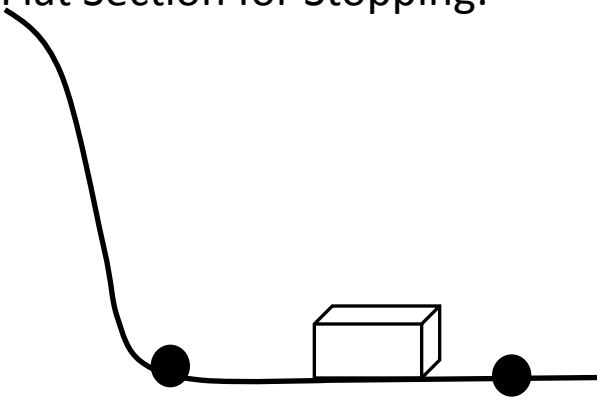
Initial Drop Notes:

Hill:



Hill Notes:

Flat Section for Stopping:



Flat Section for Stopping Notes:

Your Final Roller Coaster Written Design Proposal!

Write your letter to the Gonzales family explaining your roller coaster design. Make sure to explain how each of the sections of your roller coaster are:

•Fun and safe

•Efficient (if applicable)

Remember to use data and relevant ideas from any of your research to explain your design choices. Include the science concepts that you've learned throughout your explorations.

Hints and Tips:

Think about:

- the best way to organize your letter to communicate your ideas to the Gonzales family
- how to plan the paragraph structure that will help you to effectively explain your design
- how to write in a scientific, rather than a personal way

My Final Physics Concept Map