

Eighth Grade Instructional Segment on Kinetic and Potential Energy

Transportation Troubles:

Outcomes of car and truck accidents have inspired many innovations and solutions that make driving safer. This instructional segment uses runaway truck ramps to investigate the relationships of kinetic energy to mass and speed, and potential energy to mass of an object and height of a ramp.

Student Science Performance

Grade 8

Title:

Topic – Motion (PE/KE)

Transportation Troubles: Runaway Truck Ramps

GSE Performance Expectation

S8P2. Obtain, evaluate, and communicate information about the law of conservation of energy to develop arguments that energy can transform from one form to another within a system.

- Analyze and interpret data to create graphical displays that illustrate the relationships of kinetic energy to mass and speed, and potential energy to mass and height of an object.
- Plan and carry out an investigation to explain the transformation between kinetic and potential energy within a system (e.g., roller coasters, pendulums, rubber bands, etc.).

S8P3. Obtain, evaluate, and communicate information about cause and effect relationships between force, mass, and the motion of objects.

- Analyze and interpret data to identify patterns in the relationships between speed and distance, and velocity and acceleration.
(*Clarification statement:* Students should be able to analyze motion graphs, but students should not be expected to calculate velocity or acceleration.)
- Construct an explanation using Newton’s Laws’ of Motion to describe the effects of balanced and unbalanced forces on the motion of an object.
- Construct an argument from evidence to support the claim that the amount of force needed to accelerate an object is proportional to its mass (inertia).

Lesson Performance Expectations:

- Plan and carry out an investigation to measure the speed and acceleration of a pullback truck.
- Develop and communicate an explanation of the cause and effect of pulling the truck back and letting go.
- Construct an explanation that uses Newton’s laws of motion to explain the reactions of the pullback toy.
- Illustrate the relationships of kinetic energy to mass and speed, and potential energy to mass of an object and height of a ramp via graphical displays.
- Plan and carry out an investigation to explain the transformation between kinetic and potential energy as observed in speed and distance within a system.

[Additional notes on student supports](#)

Materials:

A: toy pullback vehicles (thrift store, toy box donations, yard sales, etc.), meter sticks, rulers, masking tape, calculators, stopwatches or cell phone timer app, string, masking tape, and ramps or toy tracks

B: Method for displaying group data: poster boards, white boards, or butcher paper

C: scales, masses (weights, washers, coins, or paper clips), masking tape

<p>Engage</p>	<p>Phenomenon-Runaway Truck Ramps</p>  <p>Communicate Students share what they know and/or understand about runaway truck ramps via photos, video footage, and prior experiences. Multiple videos can be found online.</p> <p><i>Teacher Notes: Elicit students' thoughts about the kind of material used, locations, height, etc. As students share their thoughts, probe them to provide reasoning about why these ramps are designed in certain ways.</i></p>
<p>Explore</p>	<p>Obtaining Explain that speed, mass, force, and acceleration affect the truck's motion and ability to slow down or stop. To find out more about these concepts, have students do various activities to become familiar with the energy transformations that occur in moving objects.</p> <p>Part 1: Pullback Toys Have students work with toy vehicles to gain a better understanding of force and motion, potential and kinetic energy, acceleration, inertia, etc. Demonstrate the motion of a toy pullback vehicle when it is pulled back and released.</p> <p>After investigating with the trucks to determine speed by measuring the distance traveled by the time, students discuss and describe the difference between speed, velocity, and acceleration. Each student will write his or her own explanation of each concept with a drawing (labeled with measurements and calculations).</p> <p>A: After a class discussion of acceleration, give students time, if needed to revise their previous model of acceleration and motion to illustrate their explanations for the difference between speed, velocity, and acceleration.</p> <p>Have students work in groups to devise a procedure to measure acceleration of their pull back trucks.</p> <p><i>Teacher Notes: Circulate between groups to pose questions as students develop an investigation.</i></p> <p>B. Have students use their plans to conduct an investigation to develop a way to calculate the acceleration of their pullback vehicle. Explain that they need to show their work of what worked and what didn't for other groups to view. Explain that this is how engineers and scientists test their ideas. They plan, test, and revise as they go. Provide wall space for labeled posters, whiteboards, or butcher paper displays.</p>

After time for investigation and data recording, have groups add to their display by communicating their findings and data using graphs.

In groups, students present their results showing how they determined speed, velocity, and acceleration of their truck.

After each group presents, students construct a written argument from evidence to support their experiment and compare their speed and acceleration data to other groups. (Each group member contributes to the group argument.)

C: Ask: *Would it make a difference if the trucks were loaded with different masses of cargo?*

Students obtain information by adding mass to determine the speed and acceleration on the pull-back trucks.

Teacher Notes: Have students place washers, pennies, or small mass sets on the pull-back trucks. Provide scales to mass the objects used and have students complete a data table.

Students run at least 3 trials of different mass amounts on the pull-back trucks and develop a data table to record data collected. Students repeat the trials of 3 different mass amounts and determine speed and acceleration.

Students use the experiment results to construct arguments on fully loaded cargo trucks from the phenomenon with evidence from the trials to support their arguments.

Communicating Students generate an explanation for the effect of adding mass to the acceleration of the trucks (relate to Newton's 2nd Law). Have students present their explanation on their display to share with other groups.

Teacher asks questions to clarify misconceptions. Also, teacher could relate kinetic energy of the mass as related to the speed of the truck.

Teachers could have a ramp set up for students to relate various ramp heights to the ramp height could also be emphasized in discussing potential energy of the truck as it travels down the track.

Teacher Notes: Differentiate for more advanced students by experimenting to see how long a track is necessary for the pull-back trucks to reach maximum velocity. Students would plan to collect a set of trials to determine the maximum length of tracks needed.

Would it make a difference in speed and distance travelled if the pullback trucks were placed on ramp placed at different heights?

Obtaining/Communicating Students would use visit [PhET: The Ramp](https://phet.colorado.edu) to explore the potential and kinetic energy of objects moving down a ramp to gather ideas. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; <https://phet.colorado.edu>)

Students would plan and carry out an investigation using the pullback trucks with ramps and books or blocks to simulate different heights. Students would use a sample table [Changes in Track Height](#) to describe where potential and kinetic transforms occur.

Assessment of Student Learning

Students individually write an explanation that connects speed, velocity and acceleration of the pullback trucks. Use data and graph from whiteboards to support their explanation. (They explain where in their experiment they could identify the speed, velocity, and acceleration)

Students individually write an explanation that discusses the effect of additional mass on speed, velocity and acceleration on the trucks

Part 2: Runaway Ramps

Students gather information about the relationship between kinetic and potential energy by planning and carrying out a series of investigations that allows them to identify patterns in the relationship between the speed of a truck, height of a ramp, and distance to slow down.

Teacher Notes: Some students may require a structured inquiry, while others are successful at open inquiry. If a more structured inquiry is needed, see the [Transportation Troubles: Runaway Truck Ramps](#) for suggestions.

Prompts for Writing or Discussion: What kinds of things would we need in order to investigate the relationship of height and motion/energy? What kinds of things would we need to measure and/or observe? To collect reliable data, what would you keep constant in the investigation? What would you manipulate? How would you present your outcomes?

Evaluating Students describe via graphical representation the impact of height (x-axis) on the distance and time (y-axis) the truck travels, and example [Graph Handout is included](#).

Students propose an explanation for how height impacts the amount of available potential energy available for transfer to kinetic energy.

Prompts for Writing or Discussion: How would you describe the impact of height on the car's motion? What evidence do you have to support this claim? Why do you think this occurs? Do you know any terms that are used to describe this phenomenon?

<p>Explain</p>	<p>Obtaining Students obtain information about potential and kinetic energy via virtual simulation and/or visual representations using a roller coaster.</p> <p>Suggestion for Virtual Simulation: GPB Energy in a Roller Coaster Ride</p> <p><i>Teacher Notes: When launching the simulation choose to focus on each step of the roller coaster ride. Ask students to describe the motion of the roller coaster at each step and then compare this to the pie graph of potential/kinetic energy. This will allow you to facilitate students' understanding that potential energy is associated with stored/position and kinetic energy is associated with greater motion. As part of transition to students' refined explanations about the runaway truck ramps, also guide questions to students that allow them to make connections of the position to the motion of the truck in their investigations.</i></p> <p><i>Prompts for Writing or Discussion:</i></p> <ul style="list-style-type: none"> ● <i>In this roller coaster design, which hill is the tallest?</i> ● <i>Why do you think this is the case?</i> ● <i>Do you think this is always the case?</i> ● <i>What is the PE like on this first hill?</i> ● <i>What is the KE like?</i> ● <i>What can you expect as the coaster cars begin to go downhill?</i> ● <i>What do you recognize happens each time the cars begin to move more quickly?</i> ● <i>Where are the coaster cars moving the most quickly?</i> ● <i>What is the PE like when the cars are moving the quickest?</i> ● <i>What is the total energy like throughout the coaster simulation?</i> <p>Video Suggestion: Science World - The Roller Coaster!</p> <p>Communicating Students revise their previous proposal for how height impacts the amount of available potential energy available for transfer to kinetic energy. Student revisions include a graphical representation similar to that modeled in the virtual simulation coupled with a caption that summarizes the relationship between heights (as gravitational potential energy) and distance/time traveled (kinetic energy).</p>
<p>Elaborate</p>	<p>Obtaining Challenge students to now increase the cargo carried by the truck (i.e. increase mass). Students begin by making a claim about the potential impact of distance/time rolled (dependent variable) due to increased mass (independent variable). Students then plan and investigate the impact of the truck' mass within the same system.</p> <p><i>Teacher Notes: Scaffold investigation for students as needed. See Transportation Troubles: Loaded versus Empty for suggestions.</i></p> <p>Communicating Students use data to make a scatterplot to potentially highlight patterns in the data. Students discuss potential patterns with partner, small group, and/or whole group.</p>

	<p>Evaluating Students revise their previous claims for the impact of distance/time rolled based on obtained evidence.</p> <p><i>Prompts for Writing or Discussion: What kind of unexpected results did you observe? Why do you think the truck responded in this way? What scientific principles do you think support your observations?</i></p> <p>Obtaining Students obtain information about scientific principles of kinetic energy to mass and speed, and potential energy to mass and height of an object. <i>Teacher Notes: Encourage students to organize notes in a framework.</i></p> <p>Communicating Students revise their previous model of the system to illustrate the relationship of kinetic energy (distance/time rolled) to mass and potential energy to mass and height of the truck. Students also present approximate measures of kinetic and potential energy at various stages in the system.</p> <p><i>Prompts for Writing or Discussion of approximate measures via Graphical Representation: See Transportation Troubles: Loaded versus Empty for suggestions.</i></p> <p><i>Prompts for Writing or Discussion: You can use the same handout to have students consider a CER framework for writing final explanations.</i></p>
<p>Evaluation (Formative)</p>	<p style="text-align: center;">Assessment of Student Learning</p> <p>Elicit student understandings about the relationships of kinetic energy to mass and speed, and potential energy to mass and height of an object via a new context such as skiing or cycling up and down hills.</p> <div style="text-align: center;">  </div> <p><i>Teacher Notes: As one example you could show students images of skiers performing tricks (like above) or skiers of different masses at the top of a ski ramp. Highlight various points asking students to quantify the kinetic and potential energy. Ask questions like</i></p> <ul style="list-style-type: none"> ● <i>At which point does the skier have the most potential energy?</i> ● <i>Where is the skier likely going the fastest?</i> ● <i>Why do you think this?</i> <p><i>Teacher Notes: Student results will determine student learning path.</i></p>

<i>SEP, CCC, & DCI Featured in Lesson</i>	Science Essentials
Science Practices	<ul style="list-style-type: none"> ● Planning and carrying out investigations ● Engaging in arguments from evidence ● Constructing explanations and designing solutions ● Analyzing and interpreting data
Crosscutting Concepts	<ul style="list-style-type: none"> ● Matter and Energy ● Cause and Effect
Disciplinary Core Ideas	From <u><i>A Framework for K-12 Science Education:</i></u> <ul style="list-style-type: none"> ● PS2.A: Forces and Motion ● PS2.B: Stability and Instability in Physical Systems ● PS3.C: Relationship Between Energy and Forces

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student’s Individualized Education Program.

General supports for the following categories:

<u>Reading:</u>	<u>Writing:</u>	<u>Math:</u>
<ol style="list-style-type: none"> 1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab 	<ol style="list-style-type: none"> 1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations. 	<ol style="list-style-type: none"> 1. Provide calculators as needed. 2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher can elicit student thoughts in a class discussion. Clear rules and guidelines should be given to the class on how to engage in class discussions.
2. Wait time may need to be increased when asking struggling students questions to allow them to process the question and formulate a response.

3. The teacher can also warn students in advance that they are going to be asked a question about a specific topic to cut down on the students' anxiety of waiting to see if they will be called on.
4. The teacher could choose a different format to elicit student response such as having the students record their thoughts on sticky notes and then place them in a specific spot. The teacher can then lead a discussion about the most relevant ideas that are on the board and then save some for later. These ideas could be used as a formative assessment later in the lesson by having students separate the ideas into categories based on the different laws.

Exploring:

1. The teacher should use intentional grouping to match students into working groups. Best practice is to use data to drive grouping.
2. The teacher should have students decide what they are measuring as a class, prior to giving them directions, this will help struggling students feel more invested in the lab and can help them recall this part of the lesson.
3. Struggling students may need the teacher to repeat directions more than once.
4. Struggling students may need additional time to complete the lab and construct their explanation.
5. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. This can be in writing, drawing or designing a play.
6. The students may need assistance designing an experiment. It may be beneficial for the teacher to model a design process. This could be done by making a PB&J in front of the class. Choose a recorder to record directions on the board and then have the students give you directions to make the PB&J. DO NOT do anything the students do not tell you to do. This should give the students the idea of how procedures should be written because if they do not remember to give the direction then something does not get done. (E.g. If the students do not tell you to open the jelly before trying to use the spoon to get jelly then you are trying to force the spoon through the lid.)
7. As students work on their procedure the teacher should be walking around and asking questions to help guide the students to a procedure that is going to give them a data set.
8. The teacher should provide graph paper and an example graph like the graph that the students are going to construct. This way the students have a model to refer to as they work.
9. The students may need to be reminded of how to use lab equipment like the scale.
10. Struggling students may benefit from the teacher providing them with a data table to record their data in.
11. The teacher should provide an organizer for students to record observations from the interactive.
12. Students may need additional time to plan their investigation.

Explaining:

1. When students are doing the simulation of the roller coaster the teacher should have students draw the progression of the roller coaster and label the energy at the important points in the path of the roller coaster. Then the students could use the drawing to help them make the graph.
2. Students may need additional time to revise their proposal.

Elaborating:

1. Students may need additional time to plan and carry out their investigation.
2. Struggling students may benefit from organizers to assist in the planning process.
3. Students may not know what a scatter plot is and would benefit from seeing an example. It may benefit struggling students to understand why a scatter plot is being used here.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. This can be in writing, drawing or designing a play.
5. The students may benefit from being given a framework template.

Evaluating:

1. The students may need additional time to formulate their design of the fastest train possible.
2. Students should be allowed to express their knowledge in various ways. This could include writing their argument, drawing a cartoon, designing a play or making a power point.

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Changes in Track Height

How does adjusting the height of the track/ramp affect the vehicle's motion? Use the terms **accelerate**, **distance**, **potential energy** and **kinetic energy** in your explanation to show your understanding.

Track Height	Claim	Evidence	Reasoning
1.			
2.			
3.			

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Transportation Troubles: Runaway Truck Ramps

Runaway truck ramps are found along highways and interstates to allow drivers to safely stop going down a steep hill. Runaway truck ramps are connected to the main road and made of sand or gravel.

- Your Goals:**
1. Carry out an investigation that allows you to mimic the use of runaway truck ramps.
 2. You need to identify patterns in the speed of the truck and distance required to stop based on height and mass.

Materials:

Road-like surface	Toy Truck
Ramp-like surface (filled with gravel)	Books (to elevate the ramp)
Timer/Ruler	

Possible Procedures:

1. Elevate the road-like surface to a height of 30 cm. (This will simulate the downhill slope.)
2. Affix the runaway truck ramp (filled with gravel) to create an uphill of 15 cm.
3. Create additional road space beyond the runaway truck ramp (uphill).
4. Record baseline data:
 - a. Mass of Truck: _____
 - b. Length of Downhill: _____
 - c. Length of Uphill: _____
 - d. Total Length of “Road”: _____
5. Prepare for additional measurements. (See suggested data table below.)
 - a. You will record how much time it takes the truck to stop.
 - b. You will record the distance the truck travels.
 - c. You will record any additional observations that may seem relevant to your goals.
6. Release the toy truck at the top of the 30 cm hill. Record suggested measurements.
7. Repeat at least 5 times.

Downhill: 30 cm	Trial	Distance Truck Rolled (cm)	Time Truck Rolled (secs)	Other Observations
	1			
Uphill: 15 cm	2			
Mass of Truck: _____g	3			
	4			
	5			

Initial Analysis:

How do you think the height of the downhill impacted the total distance and time the truck rolled?



What

Based on the goals of the investigation how might changing the height of the downhill impact the outcomes?

Claim: _____

What did you observe about the speed of the truck going downhill versus moving up the runaway truck ramp?



What do you think caused this?

Claim: _____

What can you change about the procedure to get an idea of how height impacts the results?

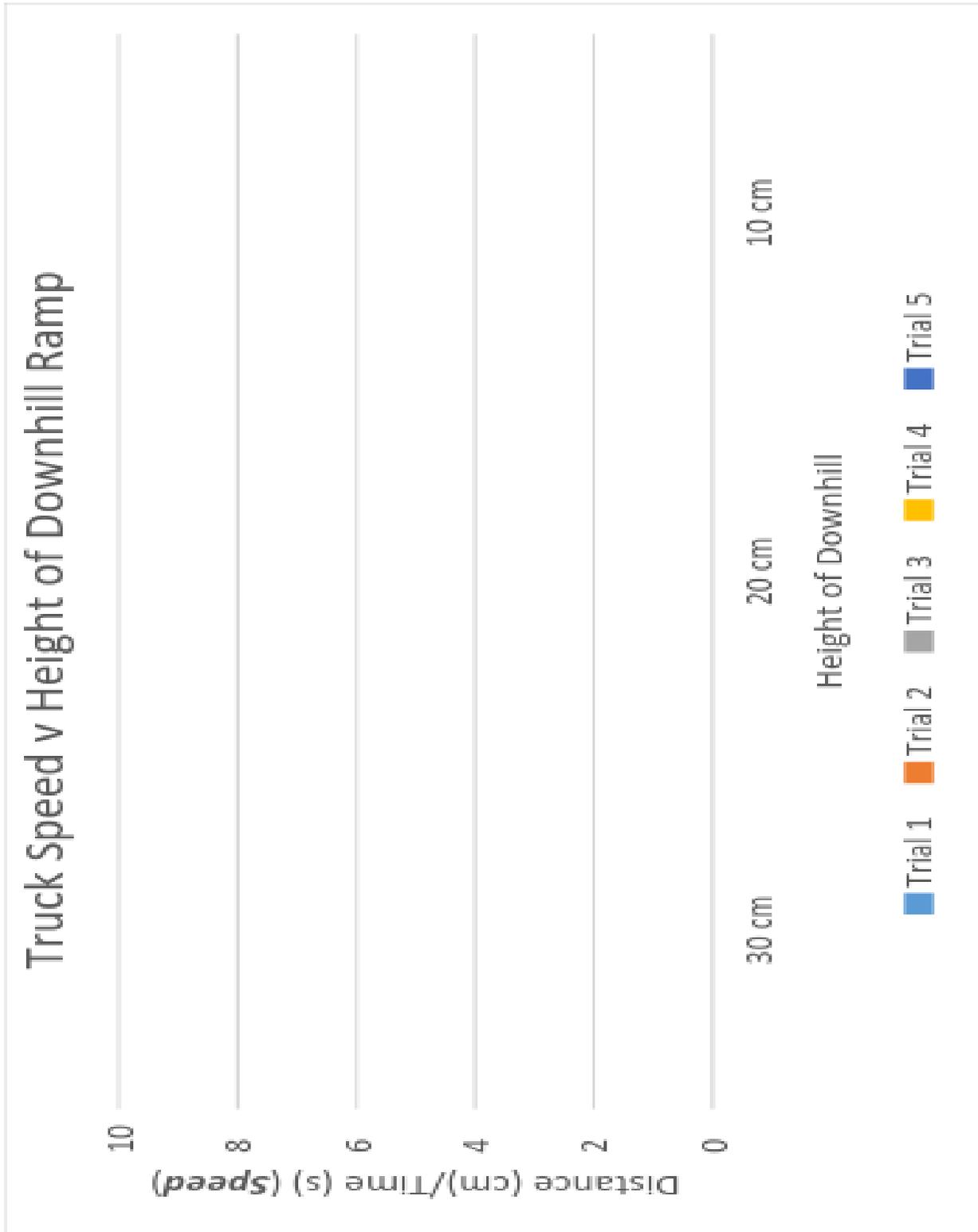
Outline a data table you could use in your investigation.

How might you present the outcomes? When your teacher checks for reliability in your investigation procedures be sure to communicate your approach.

(Check with your teacher before moving on.)

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Truck Speed vs. Height Graph Handout



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Transportation Troubles: Loaded versus Empty Truck on Runaway Truck Ramps

Truck drivers carrying a lot of cargo have to think about their speed and direction in different ways than when their truck is empty.

- Your Goals:
1. Carry out an investigation that allows you to mimic the use of runaway truck ramps when a truck is filled with cargo versus empty.
 2. Identify and graph patterns about the speed of the truck and distance required to stop based on its mass.

Materials:

Road-like surface

Toy Truck

Ramp-like surface (filled with gravel)

Books (to make elevation)

Timer/Ruler

Additional Mass (Washers or Weights)

Part One: Possible Procedures:



1. Elevate the road like surface to a height of 30 cm. (This will make the downhill slope.)
2. Affix the runaway truck ramp (filled with gravel) to create an uphill of 15 cm.
3. Allow additional road space beyond the runaway truck ramp (uphill).
4. Record baseline data:
 - a. Mass of Truck: _____
 - b. Length of Downhill: _____
 - c. Length of Uphill: _____
 - d. Total Length of "Road": _____
5. Prepare for additional measurements. (See suggested data table below.)
 - a. You will record how much time it takes the truck to stop.
 - b. You will record the distance the truck travels.
 - c. You will record any additional observations that may seem relevant to your goals.
6. Release the toy truck at the top of the 30 cm hill. Record suggested measurements.
7. Repeat at least 5 times.

	Trial	Distance Truck Rolled (cm)	Time Truck Rolled (secs)	Other Observations
Downhill: 30 cm	1			
Uphill: 15 cm	2			
Mass of Truck: _____g (Empty)	3			
	4			
	5			

Initial Analysis:

How do you anticipate adding mass of the truck will impact the total distance the truck rolled?

CLAIM: _____

Why do you think this will occur?

Part Two Procedures (Adding Mass to the Truck):



1. Use the 30 cm downhill, 15 cm runaway truck ramp _____ uphill, and additional road space beyond the runaway truck ramp.

2. Affix weights  or washers to the truck. Measure the new mass: _____ g

3. Prepare for _____ additional measurements. (See suggested data table below.)

a. You will record how much time it takes the truck to stop.

b. You will record the distance the truck travels.

c. You will record any additional observations that may seem relevant to your goals.

4. Release the toy truck at the top of the 30 cm hill. Record suggested measurements.

5. Repeat at least 5 times.

6. Repeat at different downhill heights.

Downhill:	Trial	Distance Truck Rolled (cm)	Time Truck Rolled (secs)	Other Observations
30 cm	1			
Uphill: 15 cm	2			
NEW Mass of Truck: _____g (Loaded)	3			
	4			
	5			
		Mean	Mean	

Change the length of the downhill slope

Downhill:	Trial	Distance Truck Rolled (cm)	Time Truck Rolled (secs)	Other Observations
20 cm	1			
Uphill: 15 cm	2			
NEW Mass of Truck: _____g (Loaded)	3			
	4			
	5			
		Mean	Mean	

Change the length of the downhill slope again.

Downhill: 10 cm	Trial	Distance Truck Rolled (cm)	Time Truck Rolled (secs)	Other Observations
	1			
Uphill: 15 cm	2			
NEW Mass of Truck: _____g (Loaded)	3			
	4			
	5			
		Mean	Mean	

Plot your data on a *scatterplot*. Remember to include labels for the X and Y axis and a title.

Continued Analysis

Was your initial claim accurate? _____

If not, then **revise** your **claim**. Revised Claim:

What pattern(s) becomes obvious on the scatterplot?

What scientific principles may support these outcomes?

Organize any relevant notes. Consider using a format such as Cornell Notes:

FINAL CLAIM:	
Supporting Evidence	Connected Reasoning

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