AP Physics 1 Investigation 4: Conservation of Energy

How does the compression of a spring affect the motion of a cart?

Central Challenge

In this investigation, students experiment with the concept of the conservation of energy by qualitatively investigating the relationship between elastic potential energy and gravitational potential energy. Students take a spring-loaded cart and release it so that it travels up a ramp. In addition to making observations and measurements, they make predictions as to what would happen if the angle of the ramp changed. Then, students experiment quantitatively with the relationship between the compression of the spring and the gravitational potential energy of the Earth-cart system. They do this by repeating measurements of the cart on the ramp for different compressions of the spring.

Background

The gravitational potential energy (U_g) of an Earth-cart system can be calculated with the equation $U_g = mgy$. Total energy for a closed system is conserved and so the decrease in the spring potential energy (U_{spring}) is equal to the gain in the U_g as the cart moves up the incline.

Conservation of energy is the hallmark organizing principle in all sciences. As the total energy of a closed system remains constant, a loss of one form of energy must be equal to a gain in another form of energy. Potential energy of a system is due to the interactions and relative positions of its constituent objects. Energy transferred into or out of a system can change the kinetic, potential, and internal energies of the system. Energy transfers within a system can change the amount of kinetic energy in the system and the amount of potential and internal energy, or the amount of different types of potential energy. These transfers of energy can be seen in many instances: amusement parks, electric generators, fluid flow dynamics, and heating.

Real-World Application

In this lab, students find that the loss of spring potential energy is equal to the gain in kinetic energy of a cart. In turn, kinetic energy then decreases as the gravitational potential energy increases. Operators of trains and trucks use these principles for emergency stops. At the train station, a huge spring is compressed to bring the train to rest should the brakes fail. Similarly, a truck driver might use an uphill ramp on the side of a road to bring the truck to rest. In the case of the train, the loss in kinetic energy is equal to the gain in the spring potential energy. In the case of the truck, the loss in kinetic energy is equal to the gain in gravitational potential energy. In both cases, some energy is converted into thermal energy.

People seeking thrills jump off bridges secured by a bungee cord. In this case, the energy transformations include a loss of gravitational potential energy and a gain of kinetic energy. The kinetic energy then decreases and is accompanied by an increase in the spring potential energy. Once again, some energy is converted into thermal energy.

In designing amusement park or carnival rides, it is also necessary to apply the principle of conservation of mechanical energy. For example, to build a roller coaster one must accurately predict the speed at the top of a loop to insure that the ride is safe.

Inquiry Overview

This investigation is divided into three different parts. Each part engages the student in guided-inquiry activities.

In Part I, a spring-loaded cart is placed on an incline and the cart's motion is observed once the spring is released. Students design their own experiment to test how the angle of the ramp changes the motion of the cart for the same compression of the spring.

In Part II, students design their own experiment to determine how changes in the compression of the spring change the amount of increase of the gravitational potential energy of the Earth-cart system.

In Part III, students consider how to improve their experimental design to take into account overlooked aspects of the earlier experiments. As an extension, they can also begin a new experiment where the transfer of energy out of the Earth-cart system changes the compression of the spring.

Connections to the AP Physics 1 Curriculum Framework

Big Idea 5 Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding	Learning Objectives
5.B The energy of a system is conserved.	**5.B.3.1** The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. (Science Practices 2.2, 6.4, and 7.2)

[**NOTE:** In addition to those listed in the learning objective above, the following science practices are addressed in the various lab activities: 3.1, 4.1, 4.3, 4.4, 5.1, and 6.1.]

Skills and Practices Taught/Emphasized in This Investigation

Science Practices	Activities
2.2 The student can *apply mathematical routines* to quantities that describe natural phenomena.	Part II: Students find the mathematical relationship between the compression of the spring and the gain in gravitational potential energy. Since this is not a linear relationship, students need to find alternative means of graphing and analyzing the data to secure a linear relationship (i.e., plotting the square of the compression vs. the gain in U_g in the case of many data points). Students with four data points or more should be able to show that the relation between compression of the spring and the energy the spring can provide a cart is not linear. They should also show that a quadratic relationship is supported by the data.
3.1 The student can *pose scientific questions.*	Part I: Students make observations of a cart going up a ramp and pose a question about how the angle of the incline will change the motion. Part II: Students pose questions about the relationship between the compression of the spring and the gain in gravitational potential energy of the Earth-cart system.
4.1 The student can *justify the selection of the kind of data* needed to answer a particular scientific question.	Part II: Students decide how to measure the compression of the spring and the change in gravitational potential energy. They also decide on the number of trials required.
4.3 The student can *collect data* to answer a particular scientific question	Parts I, II, and III: Students collect data as they design their own experiments and/or engage in the different data collection activities.

Science Practices	Activities
4.4 The student can *evaluate sources of data* to answer a particular scientific question.	Part III: Students consider the role that friction played in their experimental design and data collection.
5.1 The student can *analyze data* to identify patterns or relationships	Part II: Students decide if their data better fits a linear model or a quadratic model.
6.1 The student can *justify claims with evidence.*	Part I: Students create a claim regarding the motion of the cart up different inclines (e.g., more time, more distance, more speed, more height) and then use their experimental evidence to support or refute their claim.
6.4 The student can *make claims and predictions about natural phenomena* based on scientific theories and models.	Part I: Although a cart on a steeper slope will travel at a different acceleration, a different distance, and for a different elapsed time, the Earth-cart system will gain an identical amount of U_g. This allows students to use the theory of conservation of energy to make claims and predictions about the investigation.
7.2 The student can *connect concepts* in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Part II: The relationship between the compression of the spring and the gain in height leads to an understanding of the conservation of energy where the compression of the spring is related to the spring potential energy and the gain in height corresponds to a gain in gravitational potential energy. Part III: The conservation of energy principle (an enduring understanding) does not result in constant total energy in this experiment. Students recognize that this is due to the fact that the system is not closed since there are losses of energy due to friction.

[**NOTE:** Students should be keeping artifacts (lab notebook, portfolio, etc.) that may be used as evidence when trying to get lab credit at some institutions.]

Equipment and Materials

Per lab group:

- Low-friction dynamics cart with spring bumper (or spring-loaded plunger cart)
- Ramp
- Meterstick
- Stopwatch
- Assorted masses
- Books or blocks (to create incline)
- Poster-size whiteboards for sharing group work

Timing and Length of Investigation

- **Teacher Preparation/Set-up:** 10–15 minutes
- **Part I:**

  Student Investigation: 20 minutes (this includes prelab time)

  Postlab Discussion: 20 minutes (allow 5–10 minutes per group)
- **Part II:**

  Prelab: 10–15 minutes

  Student Investigation: 40 minutes

  Postlab Discussion: 40 minutes (or allow 5–10 minutes per group)
- **Part III:**

  Prelab: 15 minutes

  Student Investigation (procedural time to repeat experiments): 30 minutes

  Postlab Discussion: 20 minutes
- **Total Time:** approximately 3.5 hours

Safety

Remind students that the carts should not be on the floor where someone could slip on one. They should also consider how the spring-loaded cart could hurt someone if the plunger released near the body, especially the eye. All general lab safety guidelines should always be observed.

Preparation and Prelab

Part I of this investigation serves to determine students' prior knowledge regarding the change in the gravitational potential energy of the Earth-cart system. This then serves as the prelab for Part II.

The Investigation

Part I: Introducing the Apparatus and Experimental Design

Introduce this part of the investigation by setting up a demonstration with a spring-loaded cart on an inclined ramp (see Figure 1). Release the cart and have the students observe the motion.

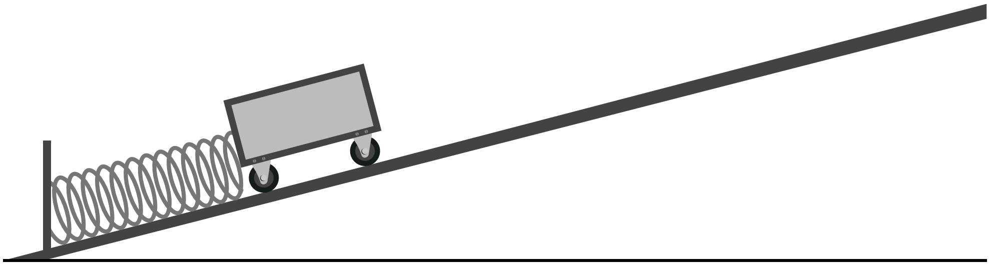

Figure 1

Prompt students: *If the cart were to be shot up a steeper vs. shallower ramp, describe how its motion will change.*

[**NOTE:**] You should not ask how the height changes, since that limits your ability to find out everything that a student is thinking about concerning the change. Expect some students to focus on greater height, greater distance, or greater time. Others may say that the cart will go a different amount up the slope or that it reaches the same height, and still others may say that it will take more or less time to reach the top. All are suitable responses, and all can be developed into experimental designs.

GUIDE STUDENTS: Instruct students to first make and justify their predictions individually, have them discuss those predictions in small groups, and then have a whole-class discussion (do NOT reveal the "right" answer). Next, have students design an experiment with the cart and ramp to investigate the question above. Each group should discuss their design and findings, and prepare to present them to the class (individual poster-size whiteboards are great for this). As a whole class, discuss the results. If there was enough friction that it affected the results, you may need to bring it into the discussion here. If there was negligible friction, the final height achieved would be the same in either case. However, since the distance travelled to reach the same height is larger on the smaller angle ramp, friction usually means it will not go as high. If not careful, students will use this observation to support the wrong conclusion.

In reviewing the experimental design, you should discuss whether multiple measurements should have been made for each angle and, if so, how many measurements would be sufficient. Ask students if one angle change was sufficient or if multiple angle changes should have been made.

If this did not come up in the class discussions, in reviewing the experimental designs and results, raise the question of the role of friction in the experiment. If there was much more friction, how would the results have changed?

Part II: Applying the Principle of Conservation of Energy

In this part of the investigation, students explore their understanding of energy and energy conservation.

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BACKGROUND: Traditionally, students have learned that the principle of conservation of energy states that energy can neither be created nor destroyed, and the total energy of a closed system remains constant. They should have also learned that the gravitational potential energy of the Earth-cart system can be calculated with the equation $U_g = mgy$. Remind them that if energy is indeed conserved, then the work on the spring from compressing it must give it some spring potential energy (U_{spring}).

Energy exists in the compression of the spring (spring potential energy [U_{spring}]), in the movement of the cart (kinetic energy [K]), and in the Earth-cart system (gravitational potential energy [U_g]).

ASK STUDENTS: As a way of testing student understanding of this principle for this part of the investigation, have students answer the following questions:

For each of the following four locations of the cart shown in Figure 2, what is the magnitude of the U_{spring}, K, and U_g at that location? Specifically, which is large, which is small, and which is zero?

Location 1: Cart is next to fully compressed spring

Location 2: Spring is no longer compressed; cart is slightly in front of spring

Location 3: Cart is halfway up the ramp

Location 4: Cart is at peak distance along the ramp

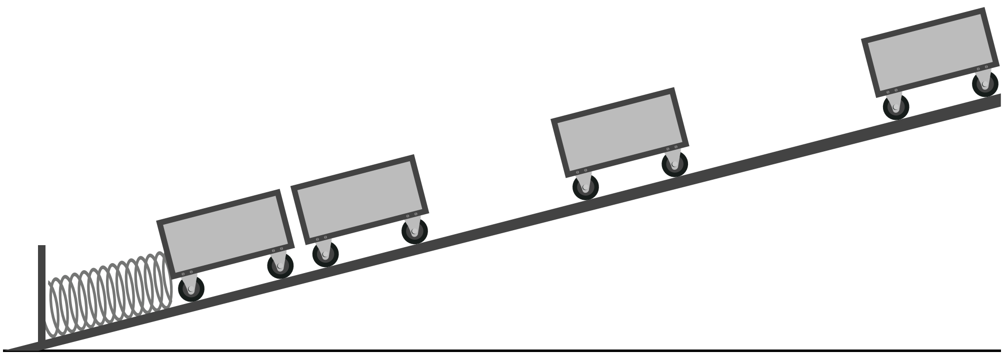

Figure 2

The students should recognize that the U_{spring} must then be equal to the U_g of the Earth-cart system after the cart gets to its peak position and no longer has any kinetic energy (K). Ask them if these statements are consistent with what they found in Part I of the investigation and to explain how they are or are not. If friction were eliminated, would the new expected experimental results be consistent with this energy explanation?

GUIDE STUDENTS: Introduce this part of the investigation by repeating the demonstration with a spring-loaded dynamics cart on an inclined ramp. Release the cart and have students observe the motion. Describe to the students that we can change the U_{spring} by compressing the spring different amounts. Some apparatus allow two possible compressions, while others allow for more possible compressions.

Ask students to design an experiment to investigate how the energy (U_{spring}) stored in the spring depends on the distance by which it is compressed. Specifically, if you increase the compression by a factor of 2, what happens to the U_{spring}?

Part II (A): Qualitative Investigation of Potential Energy

Instruct students to design an experiment to qualitatively describe the relationship between compression of the spring and the gravitational potential energy. Students should be prepared to present a convincing argument and defend their results. Again, have small groups create a presentation to be shared with the whole class (individual poster-size whiteboards work well).

Part II (B): Quantitative Investigation of Potential Energy

Instruct students to design an experiment in which they collect data in order to quantitatively support their claim. Students should complete their experiment and share their results with the class.

Part III: Improving the Experimental Design

There are a number of potential experimental errors. If students did not take these into account as they conducted their experiments in Part II, they should now consider the following:

1. What role does friction play in the experiment? How can you minimize or take into account the frictional effects?
2. If the spring could only be compressed by two values (or if the spring could be compressed for multiple values), how would your experiment change?
3. How does the amount of compression of the plunger change the manner in which you measure the distance the cart moved and/or the maximum height?

Extension

There are a number of possible extensions to this investigation that students can choose from as well as extensions they can create on their own, including:

1. How would the results change if the angle of the ramp were to change?
2. Should the experiment be done at multiple angles?
3. Which angle produces the most reliable results?
4. Do the wheels have an impact on the experimental results? Would the experiment work better with large wheels or small wheels?
5. Does the mass of the cart affect the experimental results? Which mass car would produce the most reliable results?

A more complex extension would be to have the cart descend the ramp and hit the spring. With this setup, students can investigate how much the spring compresses. They can also investigate at which point the cart is traveling the fastest.

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Common Student Challenges

Part I:
Students should observe that changing the angle of the ramp will change the distance traveled, the acceleration of the cart, and the elapsed time to reach the top. They then design a way to accurately measure the distances the cart travels since the cart is only at its peak for a moment. Changing the angle will not have a large effect on the height above the ground that the cart reaches. It will not be obvious to many students why the most important variable is the one variable (height) that does not change, or why it does not change.

Part II:
Since Part I should confirm that the gravitational potential energy gained by the Earth-cart system was always the same for the same compression, students should be comfortable with using the final gravitational potential energy as the quantity for the initial elastic potential energy. As students vary the compression distance, the observation should be that the cart's final height is directly related to the compression; however, the relationship will not be linear. If students have only two possible compressions, they should try to look for a mathematical pattern with the two data points (linear or not linear). If there are multiple compressions permitted with the apparatus, then students should make a graph and find that it is not linear.

Analyzing Results

Part I:
Having students report on large individual whiteboards is ideal. Since this investigation is qualitative in nature, students need only present their general findings. As small groups present, be sure to call particular attention to the presentations that include convincing data (especially graphic data). There are a number of variables that could have been studied (e.g., velocity, distance traveled, height attained, and elapsed time). If these have not been investigated by any group, ask them for their predictions and an explanation for that prediction.

If no team chose to investigate the height attained (and you did not encourage a team that identified height as a variable to measure it), then it will be necessary to have them do so now. Some students may wonder why you did not just tell them at the outset that height is the important variable instead of letting them "waste time" on variables that, in effect, are not as helpful. But doing so would have prevented you from being able to tap into students' sense of what variables matter and what should determine their design of the experiment; it might also have misled them into thinking that their variables were just as valuable as height attained. Telling students which variables to study limits the inquiry-based methodology being encouraged.

In reviewing the experimental design and results, you should once again discuss whether multiple measurements should have been made for each angle and, if so, how many measurements would be sufficient. You should also ask if one angle change was sufficient or if multiple angle changes should have been made.

At this point you should also raise the question of the role of friction in the experiment: if there was much more friction, how would the results have changed?

Part II:
If the apparatus has only two settings for the spring compression, that will prevent a graph from being useful. Students can still investigate if twice the compression changes the U_g by a factor of 2 or more than 2. If the apparatus allows for multiple spring compressions, then students should consider the value of making a graph.

Students should create a presentation that will provide a convincing argument supporting their findings. Have students present and discuss what was observed. Each presentation should be followed by questions from the other groups challenging the experimental technique and asking how different factors were taken into account. Encourage students to come up with alternative interpretations of the data. While the whiteboard is useful for displaying procedure, data, and graphs in a way that can be easily shared, students should use a graphing program (calculator or computer software) to evaluate the trend-line; and if linear, include the equation of the line with their graph.

Students should include enough detail so that other groups could perform their experiment. This includes the mass of the cart, description of the ramp, measurement of the angle of the ramp, and description of how the compression of the spring and the final height (for U_g calculation) were measured.

When the compression distance is varied, students should observe that height increases, but the relationship is not linear, as shown in Graph 1. This function behaves as $y = x^2$, so plotting the compression distance squared vs. the gravitational potential energy will yield a linear relationship.

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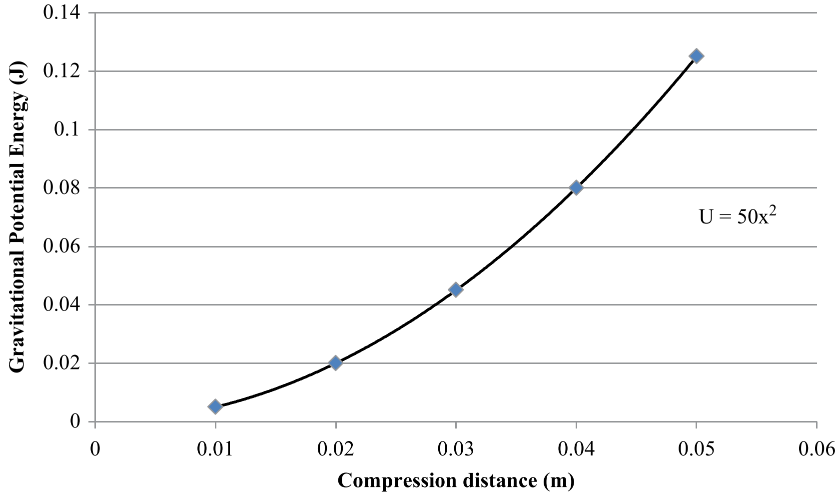
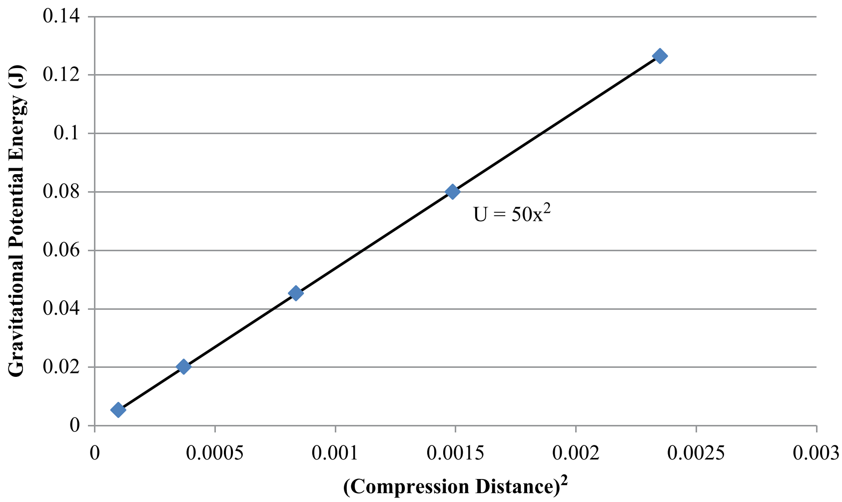


Graph 1: Gravitational Potential Energy vs. Compression Distance

An example of how to graph the compression distance vs. cart height is shown above in Graph 1, and an example of how the linearized data would appear is shown below in Graph 2:



Graph 2: Gravitational Potential Energy vs. (Compression Distance)^2

Students more familiar with approaches to making a graph linear may choose to make a log-log plot of the gravitational potential energy vs. the compression distance. They will find that the log-log plot is linear and the slope is equal to 2, which can be interpreted as the quadratic relationship. You will have to decide whether graphs should be completed by hand or by using a computer (spreadsheet or graphing program) or calculator.

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With fewer than four data points, it is not possible to disprove a linear relationship graphically. With few data points, even if more than four, the graphs may not reveal the relationship that gravitational potential energy is proportional to the square of the compression distance. This can lead you to have the students investigate the uncertainties inherent in each of their measurements. What is the uncertainty in your measurement of height? How does this lead to uncertainty in the calculation of gravitational potential energy? Similarly, what is the uncertainty in the measurement of the spring compression?

Part III:
This part speaks to subtleties in the interpretation of experimental results. As extensions, students can perform additional experiments and/or explain how they would respond to these questions and/or how they would design experiments to test them.

Students should record the final product of the experiments in either their lab journal, portfolio, or on a whiteboard display. Have students examine the best examples and give an opportunity to move around the room and record the general procedure, data and graph, and discuss the results.

Assessing Student Understanding

Part I:
After completing this part of the investigation, students should be able to make the following statement regarding the transfer of energy from the spring to the cart:

For a given compression of the spring, the energy transferred from the spring to the Earth-cart system produced a consistent height traveled by the cart regardless of the angle of the incline.

Part II:
Given a reminder about the calculation of U_g and the assumption that energy is conserved, students should be able to explain the energy decrease in the spring was equal to the energy gain by the Earth-cart system. After completing this part of the investigation, students should be able to make the following statements regarding the transfer of energy from the spring to the cart:

- *When the compression of the spring is increased, the resulting height traveled by the cart increases nonlinearly.*
- *A doubling of the compression more than doubled the maximum height of the cart.*

Students should be able to conclude that it is a quadratic relationship. They should be able to recognize that compressing the spring changed the value of the spring's potential energy (U_{spring}). Students should also see that a quadratic relationship between spring compression and U_{spring} could account for the experimental results.

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Assessing the Science Practices

Science Practice 2.2 The student can *apply mathematical routines* to quantities that describe natural phenomena.

Proficient	Using multiple data points, creates a new graph of the square of the compression vs. the gain in U_g, and determines the equation for this straight line as well as the significance of the slope and *y*-intercept. Using only two data points (due to limitations of the apparatus), illustrates that the relationship between compression of the spring and the energy the spring can provide a cart is not linear. Calculates the U_{spring} and the U_g from the data.
Nearly Proficient	Using multiple data points, creates a new graph of the square of the compression vs. the gain in U_g and determines the equation for this straight line. Using only two data points (due to limitations of the apparatus), illustrates that the relationship between compression of the spring and the energy the spring can provide a cart is not linear. Calculates the U_{spring} and the U_g from the data.
On the Path to Proficiency	Using multiple data points, graphs the compression vs. the gain in U_g and determines that it is not linear. Using only two data points (due to limitations of the apparatus), illustrates that the relationship between compression of the spring and the energy the spring can provide a cart is not linear; several errors may be present in the illustration. Identifies the values needed to calculate the U_{spring} and the U_g from the data; attempted calculations contain several errors.
An Attempt	Using a few data points, graphs the compression vs. the gain in U_g. Using only two data points (due to limitations of the apparatus), illustrates that an increase in the compression of the spring increases the energy the spring can provide a cart; several errors may be present in the illustration. Explains the quantities expressed by variables in the equation; no calculations of U_{spring} and U_g are attempted.

Science Practice 3.1 The student can *pose scientific questions.*

Proficient	Makes a claim regarding angle size and distance traveled, and provides a quantitative estimate for its justification. Makes a quantitative statement about the ratio of the compression of the spring, U_g, and the measured height. Poses scientific questions based on the translation of their claims and quantitative statements.
Nearly Proficient	Makes a claim regarding angle size and distance traveled. Makes a quantitative statement about the ratio of the compression of the spring, U_g, and the measured height; the statement contains minor errors. Poses scientific questions based on a claim or quantitative statement.
On the Path to Proficiency	Makes a claim regarding angle size and distance traveled, but several errors are present. Makes a statement regarding an increase in the spring compression and the increase in gravitational potential energy. Poses scientific questions based on a claim.
An Attempt	Makes an incomplete claim regarding angle size and distance traveled; major errors are present. Attempts to identify the relationship between the compression of the spring and how it may affect the height that the cart attains; several errors in logic are present.

Science Practice 4.1 The student can *justify the selection of the kind of data* needed to answer a particular scientific question.

Proficient	Demonstrates how to best measure the compression of the spring and the change in gravitational potential energy, and provides justification for measuring each. Explains why at least three trials should be taken for each compression of the spring and how more will be needed if the data has too much spread.
Nearly Proficient	Demonstrates how to best measure the compression of the spring and the change in gravitational potential energy. Explains why at least three trials should be taken for each compression of the spring.
On the Path to Proficiency	Identifies that measurements of the compression of the spring must be made along with the change in gravitational potential energy. Explains why multiple trials and measurement readings are made.
An Attempt	Describes the type of data being collected.

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Science Practice 4.4 The student can *evaluate sources of data* to answer a particular scientific question.

Proficient	Identifies and describes that the transfer of energy is due to the work done by frictional forces. Explains how the results would differ if friction were somehow eliminated. Describes the relationship between friction and the energy considerations of the experimental design.
Nearly Proficient	Identifies that the transfer of energy is due to the work done by frictional forces. Explains how the results would differ if friction were somehow eliminated.
On the Path to Proficiency	Articulates that there is a transfer of energy. Describes the impact of friction on the data.
An Attempt	Makes a statement regarding the presence of friction; some errors may be present.

Science Practice 5.1 The student can *analyze data* to identify patterns or relationships.

Proficient	Demonstrates that the data are not linear and that a change of axes could produce a linear relationship. Observes the graph to be quadratic and draws a new graph with the square of the compression distance on the *x*-axis. Using the regression line, writes an equation (for this line) and determines the spring constant. Demonstrates how a quadratic relationship is supported by the data.
Nearly Proficient	Observes that the data are not linear and that a change of axes could produce a linear relationship. Observes the graph to be quadratic and draws a new graph with the square of the compression distance on the *x*-axis. Draws the regression line.
On the Path to Proficiency	Observes that the data are not linear and that a change of axes could produce a linear relationship.
An Attempt	Observes that the data are not linear but cannot demonstrate why.

Science Practice 6.1 The student can *justify claims with evidence.*

Proficient	Makes a claim regarding the motion of the cart up different inclines, and provides experimental evidence and reasoning to support or refute the claim; the evidence is based on experimental data; the reasoning includes the concepts of energy transfer and the role of frictional forces.
Nearly Proficient	Makes a claim regarding the motion of the cart up different inclines, and provides experimental evidence and reasoning to support or refute the claim; the evidence is based on experimental data; minor errors are present.
On the Path to Proficiency	Makes a claim but provides insufficient evidence; the evidence is based on a statement referring to possible data.
An Attempt	Makes a claim.

Science Practice 6.4 The student can *make claims and predictions about natural phenomena* based on scientific theories and models.

Proficient	Applies the conservation of energy, and explains how the spring's compression can be used to calculate the spring potential energy. Uses the height the cart attains to calculate the gravitational potential energy from the data.
Nearly Proficient	Defines the principle of conservation of energy, and explains how the spring's compression can be used to calculate the spring potential energy. Identifies that the height the cart attains can be used to calculate the gravitational potential energy from the data; calculations are attempted with several errors.
On the Path to Proficiency	States the principle of conservation of energy, and identifies that the spring's compression is one measure of energy and that the height the cart attains represents the gravitational potential energy from the data.
An Attempt	States the principle of the conservation of energy with minor errors, and identifies that spring potential energy and gravitational potential energy are both present in the system.

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Science Practice 7.2 The student can *connect concepts* in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

Proficient	Connects the concepts of spring potential energy, the kinetic energy, and the gravitational potential energy to the big idea of conservation of energy. Tracks the total energy, the spring potential energy, the kinetic energy, and the gravitational potential energy at all points on the incline. Explains where energy losses occur and/or what energy has not been accounted for in the experiment. Provides upper limits to the loss of energy, and makes reasonable predictions of how the system would behave if the frictional forces were eliminated.
Nearly Proficient	Connects the concepts of spring potential energy, the kinetic energy, and the gravitational potential energy to the big idea of conservation of energy. Tracks the total energy, the spring potential energy, the kinetic energy, and the gravitational potential energy at many of the points on the incline with minor errors. Explains where energy losses occur and/or what energy has not been accounted for in the experiment.
On the Path to Proficiency	Connects the concepts of spring potential energy, the kinetic energy, and the gravitational potential energy to the big idea of conservation of energy with minor errors. States where each energy is a maximum. Describes the sources of energy losses.
An Attempt	Articulates the relationship that exists between spring potential energy, kinetic energy, and gravitational potential energy with several errors in logic. Identifies that energy losses occur.

Supplemental Resources

"Elastic Potential Energy." HyperPhysics. Georgia State University. Accessed September 1, 2014. http://hyperphysics.phy-astr.gsu.edu/hbase/pespr.html. [*This website provides a basic explanation of the energy stored in a spring.*]

Froehle, Peter, and Charles H. Miller. "Student Misconceptions and the Conservation of Energy." *The Physics Teacher* 50, no. 6 (2012): 367–368.

"Gravitational Potential Energy." Zona Land Education. Accessed September 1, 2014. http://zonalandeducation.com/mstm/physics/mechanics/energy/gravitationalPotentialEnergy/gravitationalPotentialEnergy.html. [*This website provides a good definition of gravitational potential energy. It shows a basic derivation of the equation from work. There are also sample problems to solve.*]

"Potential Energy." The Physics Classroom. Accessed September 1, 2014. http://www.physicsclassroom.com/class/energy/u5l1b.cfm. [*This website outlines many applications of the conservation of energy.*]