Science Learning Packet

PHYS B:
Energy Unit Packet

science learning activities for SPS students during the COVID-19 school closure.

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Due to the COVID-19 closure, teachers were asked to provide packets of home activities. This is not intended to take the place of regular classroom instruction but will help supplement student learning and provide opportunities for student learning while they are absent from school. Assignments are not required or graded. Because of the unprecedented nature of this health crisis and the District’s swift closure, some home activities may not be accessible.

If you have difficulty accessing the material or have any questions, please contact your student’s teacher.
 Phenomenon Launching Questions  
Friday, January 31, 2020  7:01 AM  

Read the Forbes article excerpt and watch the crash test video before answering these questions!  

When Answering Questions in OneNote, please highlight or change the color of your text so that I can clearly see your answers!  

There are so many characteristics of a car that can considered when trying to decide which car to buy. Color, size, gas mileage, and price are all characteristics that people may ponder when looking to purchase a new car. But what about safety? Throughout Chapter E, you will be able to apply physics principles about energy to car safety. By the end of the chapter you will be able to evaluate collisions and discuss the safety of the passengers in different types of cars.  

Launching Questions: These questions are to help you start your thinking about Energy and how it affects our lives and our safety.  

**Answer these ALONE before discussing with your table group:**  
1. When looking into buying a car, what characteristics of the car would you consider?  
2. Were you surprised by the data presented in the Forbes article or the crash test video? Explain why or why not.  

**Answer these TOGETHER with your table group:**  
1. In what way(s) do you think the design of newer cars makes them safer than older cars?  
2. What do you think might be helpful to know about energy when considering injuries from car accidents and the way cars are themselves destroyed? Brainstorm some ideas and discuss them with your group members.  

3. ALONE, name two questions do you have about vehicle safety.
OLIVIA’S FIRST CAR

Olivia is taking her driving test in three months and is excited to get her driver’s license – at last, freedom from waiting for the bus or for her dad to pick her up from softball. Olivia’s parents reminded her regularly, ever since she began dreaming about driving when entering middle school, that if she wanted her own car, she would have to save and ultimately buy the car herself. They couldn’t afford to buy a car for Olivia and her brother and sister. Olivia took this advice to heart and spent her summers lifeguarding and babysitting to save for her own car. Olivia saved $4,000 over the last four years but she only wanted to spend $3,500 on her car, so that she could also buy insurance and registration. So, after finishing Driver’s Ed and with her driving test only three months away, Olivia was ready to start shopping for her own car.

After searching on Craigslist, she narrowed her car choices down to a 1980 Volvo 244 DL for $3,000 and a 2009 Toyota Corolla for $3,500. Olivia was torn. She loved the classic feel of the Volvo and heard that even though the car was old, Volvos were incredibly reliable... But the Toyota Corolla was newer and had fewer miles.

Jake: I just like the look of the older car. I think it would be more fun to own something that is more classic. Plus, they just don't make cars like they used to.

Sara: I think that the older car is going to be much safer. Cars used to be built so the metal wouldn’t bend and crunch the same way it does now. Have you seen the aftermath from car accidents with newer cars? The new cars are so much more damaged than older cars.

Olivia’s Dad: I think you should look into some of the data and the safety tests of the two cars. Your safety is my number one concern, honey, and I think that we should be sure to do our research.

Olivia sought some advice from friends and family members while weighing her options. Read some of the opinions from her friends and family members and consider your own thoughts about the two cars.

Olivia took to the Internet to look into the safety of the two cars. She found an article from Forbes that discussed data about the safety of cars based upon their age, and also a crash test video that showed the difference in damage to an older car compared to a newer car when in a crash.
Forbes

NHTSA Confirms Newer Cars Much Safer Than Older Ones

Jim Gorzelany

We recently ran a post here on Forbes.com listing the safest and most reliable used cars for young drivers, as well as anyone who’s on a tight budget. We suggested shoppers dig a little deeper into their wallets and avoid buying older and cheaper “beater” models that may lack important safety features like stability control and side/head-protecting airbags. At that, some later models can be found on a used-car dealer’s lot fitted with high-tech accident avoidance systems like forward collision and blind-spot warning systems.

And now the National Highway Traffic Safety Administration (NHTSA) has released data that confirms that newer vehicles tend to be safer than older ones.

NHTSA determined that more passengers are killed in old cars in crashes than in new cars. The difference in death rates between vehicles built prior to 1984 is more than double that recorded for models sold between 2013 and 2017.

To quote the study’s findings, "Using the most recent fatal crash data, this analysis supports previous research in finding that a higher proportion of the occupants of older MY vehicles suffered a fatal injury. In addition, the proportion of vehicle occupants who were fatally injured increases with the age of the vehicle."

Here’s how NHTSA’s data breaks down the frequency of fatalities (deaths) in crashes by model year:

- 1984 and earlier: 55%
- 1985-1992: 53%
- 1993-1997: 46%
- 1997-2002: 42%
- 2003-2007: 36%
- 2008-2012: 31%
- 2013-2017: 26%

This study confirms conventional wisdom with hard data. Keep in mind that no matter when it was originally built, some vehicles tend to perform better than others in crash tests conducted by NHTSA and the Insurance Institute for Highway Safety. That’s why it’s always a good idea to check both organizations’ online databases when shopping for either a new or used vehicle to see how well they protect their occupants in a crash. More recent ratings from the IIHS go a step farther and consider how well a model’s forward auto-braking system (if available) can avoid or at least help reduce the effects of a collision.

After all, vehicle crashes remain the leading cause of death among teenagers, and that despite ongoing advancements in auto design and equipment, an estimated 40,100 lost their lives on U.S. roads last year.

References:
References:

E.1 Exploring Velocity

PURPOSE:
Take a moment to think about all of the ways things move. Think about how fast you’ll need to walk in order to get to school on time. Or think about how hard you’ll need to kick a soccer ball so it moves to a player across the field.
In the next few chapters you will be exploring how objects move and interact with other objects. To collect information about motion, you will be measuring velocity using a motion sensor. In this activity, you will learn to use the motion sensor and the data collection device that works with it.

Key Question: How can you represent both the speed and direction of an object
Before beginning, create a page in your lab notebook called "Energy Activity 1 Drawings and Diagrams" - this page is where you will draw all your diagrams for E1. You may end up using more than one page in your notebook. Each time you draw, be sure to label which lab the drawing goes with!

**INITIAL IDEAS:**
Imagine driving in your car. When you first start, you push on the gas pedal and the car starts moving and then picks up speed. Once you reach the speed limit, you drive at a constant speed for a while. Then, you come up to a stop sign and you use the brakes to slow the car down and make it stop.

**Answer these questions ALONE:**

1. In your "E.1 Drawings and Graphs" section, draw two different ways of showing the motion of the car during its drive. Label when the car was: speeding up, moving at a constant speed, and slowing down.

When everyone in your group is finished, compare answers and make sure you understand everyone else's ideas. Remember, you don't have to (and shouldn't) agree at this point!!
## E.1 Learning Tracking Tool

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Claim: What did we figure out?</th>
<th>Evidence: What did we do?</th>
<th>Self-Assess: Where am I with my understanding?</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1: How Can Graphs Show Motion?</td>
<td>Answer the experimental question. Summarize key information. You may copy/paste key claims from the lab.</td>
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<tr>
<td>#2: HOW DO GRAPHS SHOW SPEEDING UP, SLOWING DOWN, AND CONSTANT SPEED?</td>
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<tr>
<td>#3: How Does A Velocity-Time Graph Show Speed and Direction?</td>
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<tr>
<td>#4: What Do Positive and Negative Velocity Mean?</td>
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</tbody>
</table>
Experimental Question: How Can Graphs Show Motion?

Read Step 1 in your Energy Book. Be sure to give everyone a chance to both collect and create data.

Q1. What settings were you able to change on the data collection device? What is the purpose of changing each setting?

Q2. How can you change the motion sensor to collect data for different types of objects

Read the toolbox in the Energy Book and compete step 3, 4, 5 and 6. Draw the graph in step 6 in the "E.1 Drawings and Graphs" page in your notebook.

See Step 5 Video Here

Q3. What do you think the graph is showing about the person’s velocity?

Complete step 7 in the Energy Book.
**Experimental Question: HOW DO GRAPHS SHOW SPEEDING UP, SLOWING DOWN, AND CONSTANT SPEED?**

Read and complete Step 1-3 in your Energy Book. Draw your graphs on your "E.1 Drawings and Graphs" page in your notebook.

Q1. Compare your “prediction” and “observation” graphs. How are they different? What are some reasons for the differences?

Read and complete step 4 in your Energy Book. Attach the handout into your "E.1 Drawings and Graphs" page in your notebook.

Q2. In 2-3 sentences, summarize how to show motion on a velocity-time graph. Write your explanation like you are trying to teach someone who hasn’t done it before.
Experimental Question: How Does A Velocity-Time Graph Show Speed and Direction?

Read and complete Step 1-3 in your Energy Book. Draw your graph on your "E.1 Drawings and Graphs" page in your notebook.

Step 4: Complete the statements below by filling in the blanks with the appropriate word: above or below.
- When the cart moved toward the motion sensor, the graph was __________ the X-axis.
- When the cart moved away from the motion sensor, the graph was __________ the X-axis.

Q1. Based upon your observations, describe how a graph can show both speed and direction.

Q2. How would you know if an object was moving away from or toward the motion sensor just by looking at the graph?

Read and complete step 5 and 6 in your Energy Book.

Q3. Look at the Y-axis of your graph (Remember: In this case, the Y-axis is the one labeled Velocity). What is the velocity of the cart when it changed direction?
Experimental Question: What Do Positive and Negative Velocity Mean?

Click on this link: https://archive.cnx.org/specials/e2ca52af-8c6b-450e-ac2f-9300b38e8739/moving-man/

Read and complete Step 1-4 in your Energy Book.

See Steps 2-5 Video Here

Q1. Was the graph positive (above the X-axis) or negative (below the X-axis)?

Read and complete Step 5 in your Energy Book.

Q2. Was the graph positive (above the X-axis) or negative (below the X-axis)?

Q3. What does the sign (+ or -) of the velocity tell us about the motion of the object? Use specific examples from this activity to support your ideas.

Step 6: Complete the statements below to summarize your observations from this experiment.

- When the man moves from left to right on the number line (ruler on the simulation), the graph is _______________ the X-axis. This means that the velocity is _______________.
- When the man moves from right to left on the number line (ruler on the simulation), the graph is _______________ the X-axis. This means that the velocity is _______________.

E.1 Summarizing Questions

1. A group of students collected the graph data shown on the right. Describe how you think the students collected the data (walking or with a cart) and what the graph shows about the object’s motion.

2. Claudia and Samantha are discussing how to interpret the velocity-time graph below.

Who do you agree with and why?

Claudia: It looks to me like the cart was moving at a relatively constant speed. Then at 2 seconds the cart sped up and then slowed back down. For the rest of the graph it moved at a constant speed.

Samantha: I disagree. I think the cart was moving at a constant speed the whole time. I think that spike in the data is from something getting in the way of the motion sensor. Maybe the hand got in the way.

I agree with...

3. Two carts, cart A and cart B, are moving in opposite directions. Cart A is moving away from a motion detector at 2 m/s and cart B is moving toward the motion detector at 1 m/s. a. Which cart’s velocity would be positive and which would be negative? Describe your reasoning.

b. Graph the velocity of cart A and cart B in the "E.1 Drawings and Graphs" section of your notebook. Describe your answer or insert a picture here.

c. Velocity can be represented using arrows. Draw the two carts in your "E.1 Drawings and Graphs" section in your notebook and use arrows to represent the motion of each cart. Describe your answer or insert a picture here.

The velocity of cart ___ would be positive and the velocity of cart ___ would be negative because...

4. The velocity-time graph shows the motion of two objects that was collected using a track, cart, and motion sensor. Complete the table to describe the motion of object A and object B. Indicate how the speed is changing and the direction the object is moving:

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Object A Speed</th>
<th>Object B Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1 second</td>
<td></td>
<td></td>
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<tr>
<td>1-2 seconds</td>
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<tr>
<td>2 seconds</td>
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<tr>
<td>2-3 seconds</td>
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<tr>
<td>3-4 seconds</td>
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</table>

To indicate speed: state if the object is speeding up, slowing down, moving at a constant speed, or stopped.
To indicate the direction: state if the object is moving toward or away from the motion sensor.
E.1 Scientist Ideas Reading

**E.1 SCIENTISTS’ IDEAS READING**

**Instructions:** As you read the Scientists’ Ideas, think about how they relate to the evidence you collected in the activity.

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**E.1a**

Graphs tell a story: Graphs are used in science as a way of visually showing (representing) data. A graph can tell a story about the motion of an object.

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Graphs can be used to describe the story of an object’s motion. Graphs have two axes: the X-axis and the Y-axis. The axes are two lines: the horizontal axis (side-to-side) and the vertical axis (up-and-down).

All graphs need to include a title and labels for the X-axis and Y-axis (including units). In this activity, the Y-axis represented “velocity” on the Y-axis and “time” on the X-axis. Usually when graphing a variable and time, time will be on the X-axis of the graph.

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**E.1b**

**Velocity:** Velocity gives information about both the speed and the direction. In graphs, the X-axis represents time and the Y-axis represents velocity.

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Speed tells you how fast an object is moving but does not provide information about the direction. The units for speed are often meters per second (m/s). Velocity gives both the speed and the direction for an object. Velocity-time graphs indicate the direction of motion based on whether the graph is above or below the X-axis (positive velocity or negative velocity). The direction change is indicated by the graph crossing the X-axis (therefore changing from moving away to moving towards the motion sensor). When the object turns around, the velocity is zero.

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**E.1c**

**Vectors:** Scientists use arrows, called vectors, to represent speed and the direction of motion. Vectors are labeled using a symbol with an arrow above it.

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Velocity is represented through vectors. Speed alone does not include information about direction. Whenever you see speed and direction are given. For example, $v = 5 \text{ m/s}$ means “moving 5 m/s away from the motion sensor,” and $v = -3 \text{ m/s}$ means “moving 3 m/s toward the motion sensor.”

In your experiments, you observed that objects moving away from the motion sensor have a positive velocity and objects moving toward the motion sensor have a negative velocity. You can imagine the motion sensor on a number line (as shown in the picture above).

In the simulator, motion toward larger numbers on the number line is represented by a positive velocity and motion toward smaller numbers on the number line is represented by a negative velocity.

This type of agreement among scientists is called a **convention** (which is like a rule); it makes scientific work easier if everyone follows the same rule. The simulator shows this convention with the ruler. When the moving man moves from -1 meter to 5 meters, his velocity is positive. When he moves from 2 meters to -1 meter, his velocity is negative.
Respond to the following questions individually in your physical lab notebook:

1. When making a graph, what must always be included on the graph?
2. How are speed and velocity related? How are they similar/different? Describe why velocity is a vector and speed is not.
3. How can you tell the direction an object is moving based on a velocity-time graph? How can you tell the speed an object is moving based on a velocity-time graph?
4. Draw a velocity-time graph for an object originally traveling at -3 m/s. The object then slows down and turns around.
5. Describe the motion of the object for each of the velocity-time graphs below. Include a description of the time intervals when the object is speeding up, slowing down, moving at a constant speed, and stopped. Also include the direction that the object is moving. (Away or toward the motion sensor.)
Apply physics principles developed in the activity by grappling with the questions below.

An article1 from Popular Mechanics stated: Car crashes are still extremely deadly—32,719 Americans died in car accidents in 2013, or almost 90 people a day. But the number of people dying in car crashes—particularly when expressed as how many people per 100,000 die in an auto accident—has essentially steadily declined since the early 1970s.

Popular Mechanics explains that this is because newer cars are engineered with crumple zones that allow the passengers in a car to slow down over a greater period of time during a collision, when compared to a car without the same crumple zone technology.

1. Think about a time when you slowed down very, very quickly compared to a time when you slowed down more slowly. How did these two experiences feel (comparatively)?

2. On one set of graph axes, draw the following two velocity-time graphs (label your graphs older car and newer car).
Graph 1: for the passengers in an older car involved in a collision. The passengers slow down from 40 miles per hour to 0 miles per hour in 0.25 seconds.
Graph 2: for the passengers in a newer car (with crumple zones) involved in a collision. The passengers slow down from 40 miles per hour to 0 miles per hour in 1.5 seconds.

3. Why do you think passengers tend to experience fewer injuries in cars that slow down more slowly (as in, they slow down over a greater period of time) during a collision?

4. Extension: Consider airbags that are installed in newer cars.
a. Research some of the history of airbags. When were they first used in cars? How did they influence fatality and injury rates in car accidents?

b. In terms of velocity, how does an airbag add additional safety for passengers?
E.2 Motion and Energy

E.2 Motion and Energy

Sunday, March 29, 2020 11:20 PM

See the idea of energy in many ways in everyday life. Perhaps you’ve heard talk of an “energy crisis” when fuel supplies run low; people eat “energy bars” to keep them going; and we say small children have “lots of energy” when they run around. Think about different types of energy you have heard of or experienced in your life.

Key Question: What inferences can you make about an object’s energy by observing its motion? How can you represent changes in energy?
INITIAL IDEAS:
Using a low-friction cart, track, motion sensor, and data collection device, a lab group collected the velocity-time graph shown on the right. One group member pushed the cart so that it increased in speed. Then another group member gave the cart a gentle tap the opposite way and then let go so the cart slowed down, but did NOT come to a complete stop.

Answer these questions ALONE:

1. Copy the graph above into your laboratory notebook. On the graph, circle all of the times when you think the hand was in contact with the cart.

2. During the time shown on the graph:
   a. When do you think the cart had the most motion energy?
   b. When do you think the cart had the least motion energy?
   c. When do you think the motion energy of the cart was changing? What do you think made the motion energy change?

When everyone in your group is finished, compare answers and make sure you understand everyone else's ideas. Remember, you don't have to (and shouldn't) agree at this point!!
<table>
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<th><strong>Experiment</strong></th>
<th><strong>Claim: What did we figure out?</strong></th>
<th><strong>Evidence: What did we do?</strong></th>
<th><strong>Self-Assess: Where am I with my understanding?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>#1: How can you make inferences about energy using observations of speed?</td>
<td>Answer the experimental question. Summarize key information.</td>
<td>Summarize activities with a description and/or picture.</td>
<td></td>
</tr>
<tr>
<td>#2: What inferences about energy transfer can you make from observations of speed?</td>
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<td></td>
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<tr>
<td>#3: When does energy transfer happen?</td>
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Optional Vocab List:

<table>
<thead>
<tr>
<th><strong>Important Words</strong></th>
<th><strong>Notes or Definitions</strong></th>
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**Key Question**

What inferences can you make about an object’s energy by observing its motion? How can you represent changes in energy?

**Phenomenon**

Where does the energy go in a newer vs an older car?

**What questions do I have?**

What additional information do you need to understand the phenomenon?
Experimental Question: How can you make inferences about energy using observations of speed?

Read the Tool Box in your Energy Book out loud with your group. You may want to define new words on your learning tracking tool.

Read Step 1 in your Energy Book.

Q1. What are some other examples of observations and inferences?

Read and complete Step 2 in your Energy Book; look at the handout from your instructor, copied below:

Read the Tool Box on the top of page 19, and read and complete Step 3 in the Energy Book:
**Experimental Question: What inferences about Energy Transfer can you make from observations of speed?**

Read and complete Steps 1-3 in your Energy Book. Be sure to draw your two graphs on the SAME axes.

[See Step 2 Video Here]

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Q1. Does the energy of the target cart change during the collision? What evidence supports your idea?

Q2. Does the energy of the launched cart change during the collision? What evidence supports your idea?

Read the Step 4 Tools of the Trade.

Q3. Based upon the energy diagram, which object was the energy transferred from? Which object was the energy transferred to? Is this consistent with the inference you made in your experiment?
Experimental Question: When does energy transfer happen?

Read and complete Steps 1-2 in your Energy Book using the handout below:

Q1. Describe your reasoning for each of your predictions

Complete Steps 3-4 in your Energy Book using the video and the handout to the right: See Video Here (Speeding Up)

Q2. Do your observations of the slow motion video make sense to you? Why or why not?

Q3. What inferences can you make from the slow motion video about when energy is being transferred from the hand to the cart? Describe your reasoning

Read the ToolBox on the top of page 23.

Q4. Draw an energy diagram for the time the hand pushes the cart to speed up. Include evidence (what you observed) for each change in energy.

Read and complete step 5 using the handout to the right.

Q5. Describe your reasoning for your prediction.

Read and complete step 6-7 using the handout below. See Video Here (Slowing Down)

Q6. Do your observations of the slow motion video make sense to you? Why or why not?
### E.2 Summarizing Questions

<table>
<thead>
<tr>
<th>SUMMARIZING QUESTIONS</th>
<th>MY ANSWERS</th>
<th>ADDED IDEAS FROM THE READING</th>
</tr>
</thead>
</table>
| 1. In a game of pool, the 8-ball collides with the 6-ball. The 2-ball stops and the 8-ball speeds up during the collision. Draw an energy diagram for the energy transfer that occurs when they are in contact. Include evidence in the circle.  
**Before Contact:** | | |
| **After Contact:** | | |
| 2. The graph on the right shows the motion for a cart that was pushed multiple times by a hand.  
a. On the graph, circle when a hand was in contact with the cart.  
b. What evidence from this lab did you use to decide how to circle the graph?  
c. Label on the graph where the energy is lowest, highest, increasing, and decreasing.  
Describe your reasoning.  
d. In terms of energy, describe what happens when the hand is in contact with the cart. What evidence supports your ideas? | | |
| 3. Shown on the right are velocity-time graphs for two carts. One cart (Cart A) was pushed by a hand and then hit the second cart (Cart B), similar to what you observed in the experiment.  
a. Circle when the hand was in contact with Cart A.  
b. Use a different color to circle when the carts were in contact with each other.  
c. Complete the energy diagram below for the energy transfers:  
Energy Giver:  
Energy Receiver/Giver:  
Energy Receiver:  
**Evidence:** | | |
| 4. The graph on the right shows a cart’s velocity. For each time interval given in the space below, indicate if the cart’s kinetic energy is zero, increasing, decreasing, or constant.  
0.0s to 1.0s:  
1.0s to 2.0s:  
2.0s to 3.0s:  
3.0s to 4.0s:  
4.0s to 5.0s: | | |
Part One:
1. What observation would lead you to infer that an object’s kinetic energy has changed?

2. Summarize the relationship between speed and kinetic energy.

3. Does the direction an object is moving affect the kinetic energy? Describe your reasoning.

4. Draw a velocity-time graph for someone giving you a quick push on a skateboard and then letting go. Hint: you began stopped, your speed increased, and then you traveled at a constant speed. Circle and label when your friend was pushing you.

6. The graph on the right shows a cart’s velocity. Over the 5 seconds shown, a hand has come into contact with the cart (one or more times). Draw the graph in your notebook and circle when the hand was in contact with the cart.

7. In an energy transfer between two carts, what happens to the kinetic energy of the energy giver? What about the energy receiver’s kinetic energy?

8. Draw an energy diagram for a baseball bat that hits a baseball. Include evidence.

Part Two:
2. Using your responses to the previous question, draw an energy diagram showing how energy transfers when a soccer player kicks a ball.

5. How might you observe that you have increased or decreased in chemical potential energy?

6. Evaluate these two nutrition labels.

A. Based upon the calories alone, which provides the greatest amount of chemical energy to your body

B. Based upon the total carbohydrates and the sugars, which will provide the longest lasting chemical energy?
E.2 Scientists’ Ideas Reading - Part 1

Instructions: As you read the Scientists’ Ideas, think about how they relate to the evidence you collected in the activity.

Observations and inferences: Inferences are conclusions made from observations.

Imagine seeing a stove burner glowing red, you might conclude that it is hot and decide not to touch it. This is an example of an observation and an inference. You observed the red burner and inferred that it was hot. We must make inferences about energy since we cannot observe it directly. Remember, observations are gathered using your senses—what you see, taste, feel, hear, or smell. Inferences are conclusions that are drawn from observations.

Kinetic energy: Inferences about an object’s motion energy are made from observations of its speed. Scientists call this energy of motion kinetic energy. It can be abbreviated KE.

Kinetic energy changes as the speed changes. As you saw in this lab, you can infer that an object’s kinetic energy is zero when the speed is zero, and the kinetic energy is increasing when its speed is increasing. The faster an object is moving, the more kinetic energy it has. An object’s direction does not affect its kinetic energy; it is only how fast the object is moving that matters. Therefore, scientists discuss kinetic energy in terms of speed, not velocity.

The statements about kinetic energy in the velocity-time graph below are inferences. Carefully read the graph to see that it is only the speed, not the direction the object is moving, that affects the kinetic energy.

![Velocity-Time Graph for the Car’s Journey](graph.png)
**Energy transfer:** Energy can be transferred between two objects. When energy is transferred from an object, it *decreases* in energy and the object that receives the energy *increases* in energy. This energy decrease and increase can only happen when there is an energy transfer.

Changes in speed (and therefore changes in energy) are a result of the **transfer of energy** that happens between the objects. When there is a push or pull, one object can give energy to another object; this is an **energy transfer**.

From the slow motion video, you observed that in order for an object to change speed, there had to be contact in the form of a push or pull. Therefore, we can infer that increases and decreases in kinetic energy occur during this contact.

In this activity, you observed the speed of two carts: a *launched cart* that hit a *target cart*. During the collision, the launched cart slowed down, while the target cart sped up. From this observation of the change in speed, it is possible to make the inference that energy is transferred *from* the launched cart to the target cart. This **energy transfer** can be represented using an energy diagram.

**Energy diagrams:** Energy diagrams show energy transfer between objects.

Energy diagrams show the energy transfer between the carts (or any objects). The cart that initially started with the energy, the *launched cart*, is the **energy giver** because it supplies the energy that is transferred. The *target cart* is the **energy receiver** because it gains the transferred energy.
Respond to the following questions individually in your lab notebook:

1. What observation would lead you to infer that an object’s kinetic energy has changed?

2. Summarize the relationship between speed and kinetic energy.

3. Does the direction an object is moving affect the kinetic energy? Describe your reasoning.

4. Draw a velocity-time graph for someone giving you a quick push on a skateboard and then letting go. Hint: you began stopped, your speed increased, and then you traveled at a constant speed. Circle and label when your friend was pushing you.

5. What evidence suggests that the launched cart had kinetic energy before colliding with the target cart and the target cart did not?

6. The graph on the right shows a cart’s velocity. Over the 5 seconds shown, a hand has come into contact with the cart (one or more times). Draw the graph in your notebook and circle when the hand was in contact with the cart.

7. In an energy transfer between two carts, what happens to the kinetic energy of the energy giver? What about the energy receiver’s kinetic energy?

8. Draw an energy diagram for a baseball bat that hits a baseball. Include evidence.

9. The graphs below show the motion for two different carts.
   a. On each graph, circle when a hand was in contact with the cart.
   b. Describe how you decided what to circle on the graphs and why.
E.2 SCIENTISTS’ IDEAS READING – PART 2

Instructions: As you read the Scientists’ Ideas, think about how they relate to the evidence you collected in the activity.

Stored chemical potential energy: Chemical potential energy is “stored” in our bodies.

It is common to use the idea of energy to describe how you feel. After a good night’s sleep you might get up and feel full of energy. But after a long day you might feel drained of energy. This suggests that people can “store” energy. This is indeed true; the food we eat provides energy to our bodies. Scientists call this chemical potential energy (CPE).

Imagine pushing a car. After pushing the car for a while, you would begin to feel tired. This is an indication that you have transferred your chemical potential energy into the car. In this energy transfer, your chemical potential energy decreased and the car’s kinetic energy increased. An energy diagram can be used to show this energy transfer.

The same type of energy transfer happens when you push the cart with your hand, but on a much smaller scale. Unlike kinetic energy, it is much more challenging to make inferences about chemical potential energy from observations. This is because chemical potential energy has to do with how the atoms in your body are arranged, and atoms are too small for us to observe directly.

Chemical potential energy and food: Chemical potential energy comes from food and is used for our bodies to move.

Different foods have different amounts of chemical potential energy depending upon the type of food. Scientists conduct experiments in order to determine how much chemical potential energy is in food; they use a unit of energy called a calorie to express the amount

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of energy that is available for humans. When you eat food, you can think of the amount of calories as the amount of chemical potential energy that you eat.

Not all types of chemical potential energy in food turn into usable energy at the same rate. Have you ever noticed that after you eat a candy bar, you will experience a burst of energy before again feeling tired? This is because the chemical energy in candy bars is in the form of small sugar molecules (simple carbohydrates) that quickly release energy. Once you use the energy, the candy bar no longer provides you with “fuel,” and you may begin to feel tired. On the other hand, vegetables and whole grain breads have more complex molecules called a complex carbohydrate. These take much longer to turn into energy, so they provide you with chemical potential energy for a longer amount of time. The “Total Carbohydrate” shown on a nutrition label indicates the total amount of simple and complex carbohydrates. The amount of simple carbohydrates is indicated by the “ Sugars.”

**Nutrition Facts**

<table>
<thead>
<tr>
<th>Serving Size 1 Candy Bar (1.86g)</th>
<th>Serving Per Container 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calories</strong> 229</td>
<td>Calories from Fat 10%</td>
</tr>
<tr>
<td><strong>Total Fat</strong> 11.46g</td>
<td><strong>Saturated Fat</strong> 5.97g</td>
</tr>
<tr>
<td><strong>Trans Fat</strong> 0.19g</td>
<td><strong>Cholesterol</strong> 4.23mg</td>
</tr>
<tr>
<td><strong>Sodium</strong> 86.63mg</td>
<td><strong>Total Carbohydrate</strong> 29.54g</td>
</tr>
<tr>
<td><strong>Dietary Fiber</strong> 0.89g</td>
<td><strong>Sugars</strong> 21.87g</td>
</tr>
<tr>
<td><strong>Protein</strong> 3.22g</td>
<td>6%</td>
</tr>
</tbody>
</table>

*Percent Daily Values are based on a 2,000 calorie diet.

**Chain energy transfers**: Scientists often track how energy transfers between multiple objects. In these situations, a chain transfer diagram is useful for representing the energy transfers.

In situations where you need to show more than one energy transfer, you may want to draw a **chain transfer** energy diagram.

For example, when a basketball player throws a basketball. The food the player ate was the initial energy giver. The energy in the food is turned into chemical potential energy in the player's body. This is the energy the player uses to throw the basketball.
Respond to the following questions individually in your lab notebook:

1. Think about a soccer player using her muscles to kick a ball:
   a. Energy giver: What or who supplied the energy?
   b. Energy decrease: What type of energy changed in the giver?
   c. Energy receiver: What or who gained energy?
   d. Energy increase: What type of energy changed in the receiver?

2. Using your responses to the previous question, draw an energy diagram showing how energy transfers when a soccer player kicks a ball.

3. Draw an energy diagram for a person who is pushing his friend on a bicycle.

4. What is chemical potential energy? Where does this energy come from?

5. How might you observe that you have increased or decreased in chemical potential energy?

6. Evaluate these two nutrition labels.
   a. Based upon the calories alone, which provides the greatest amount of chemical energy to your body?
   b. Based upon the total carbohydrates and the sugars, which will provide the longest lasting chemical energy?

7. A friend is preparing to play in a full-day baseball tournament. What would you tell him to look for on a nutrition label to ensure that he would have enough chemical potential energy for the whole day?
Apply physics principles developed in the activity by grappling with the questions below.

1. The Popular Mechanics article discusses that the crumple zones:

   “spread the energy of the car in motion around to the other structural components of the car. This... allows kinetic energy to go other places besides the human driver and passengers.”

As a passenger slows down from 40 miles per hour to 0 miles per hour, an enormous amount of energy is dissipated. Discuss where the energy goes:

a. In a newer car with crumple zones:

b. In an older car without crumple zones:
E.3 Slowing and Stopping

PURPOSE: When exploring energy transfers in previous activities, you observed that the speed of the objects in contact can change very quickly. For example, when a hand pushes a cart, the cart will quickly increase in speed. You may have also noticed that after the hand releases the cart, the cart slowed down very slightly before reaching the end of the track and stopping. Why does the cart slow down after being pushed? What do you think causes this change in speed and energy?

Key Question: Why do objects slow down and stop?
**INITIAL IDEAS:**
Imagine a student pushes a block across the table. The block speeds up when the student pushes it, but immediately after the student releases the block, it starts to slow down.

**Answer these questions ALONE:**

1. When the block's speed decreases, its kinetic energy also decreases. What do you think happens to the block's kinetic energy? Do you think it goes somewhere, or does it just disappear?

2. What evidence would you need to collect to test your ideas from the previous question?

When everyone in your group is finished, compare answers and make sure you understand everyone else's ideas. Remember, you don't have to (and shouldn't) agree at this point!!
Learning Tracking Tool for Energy 3: Slowing and Stopping

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Claim: What did we figure out?</th>
<th>Evidence: What did we do?</th>
<th>Self-Assess: Where am I with my understanding?</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1: What can you infer about energy from observations of objects slowing down?</td>
<td>Answer the experimental question. Summarize key information.</td>
<td>Summarize activities with a description and/or picture.</td>
<td></td>
</tr>
<tr>
<td>#2: How would an object move without friction?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Optional Vocab List:

<table>
<thead>
<tr>
<th>Important Words</th>
<th>Notes or Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Key Question**

Why do objects slow down and stop?

**Phenomenon**

The Popular Mechanics article discusses that the crumple zones “spread the energy of the car in motion around to the other structural components of the car. This... allows kinetic energy to go other places besides the human driver and passengers.”

1. Where does the energy go in a new car with a crumple zone compared to one without a crumple zone?

2. How is energy transfer different when a passenger in a car slows down quickly compared to slowly?
What questions do I have?
What additional information do you need to understand the phenomenon?
Experimental Question: WHAT CAN YOU INFER ABOUT ENERGY FROM OBSERVATIONS OF OBJECTS SLOWING DOWN?

Read Step 1 in your Energy Book.
See Step 1 Video Here

Q1. Draw the velocity-time graph for the block in your notebook and label when the hand was in contact with the block.

Q2. Describe how your graph compares with another group’s graph. How are they similar and different?

Q3. After releasing the block, what do you think happened to the block’s kinetic energy? Do you think it was transferred into another form of energy or did it disappear? Describe your reasoning. If you think it was transferred into another form of energy, what kind?

Read and complete Step 2-4 in your Energy Book using the table below.
See Infrared Video Here

<table>
<thead>
<tr>
<th>Observation</th>
<th>Energy Inferences</th>
</tr>
</thead>
</table>

Q4. When two objects rub together, do both increase in temperature or only one? What is happening in terms of energy? What evidence supports your claims?

Read the Tools of the Trade Box on the top of page 36.

Q5. Based on your observations from the previous steps and the Tools of the Trade reading, what general inference can you make about the temperature of objects when they rub together?

Q6. Reconsider the question about what happened to the block’s kinetic energy. Using your understanding of rubbing your hands together, describe what happened to the block’s kinetic energy as it slowed to a stop.

Read the Tools of the Trade Box on the bottom of page 36.

Q7. Using to the Tools of the Trade reading and the energy diagram, write a 3 to 4 sentence description for why the block slows down in terms of energy.

Read Step 5 and examine the graph in your Energy Book.

Q8. What happened to the cart’s speed after the initial tap?

Q9. What inferences can you make about the cart’s kinetic energy after the initial tap? In other words, did the kinetic energy increase, decrease, or remain constant?

Q10. What can you infer about what happened to the kinetic energy? In other words, was the energy
transferred (if so, where?) or did it disappear? Describe your reasoning.

Q11. Draw an energy diagram for this energy transfer for the time the cart was slowing down while traveling along the track. Be sure to include evidence. Compare your energy diagram with another group’s.

Q12. Why does friction make objects slow down and stop? Include your observations and your inferences about the energy conversions/transfer.
Experimental Question: HOW WOULD AN OBJECT MOVE WITHOUT FRICTION?

Java Simulation Link Here

Read and Complete Steps 1-4 in your Energy Book.
If you are unable to open the simulation, see video here

Q1. How do your observations from the simulator compare to your observations from the previous experiment when you observed a block and a cart slow down after being pushed?

Q2. Do you think the temperature (and thermal energy) of the filing cabinet and the ground would increase, decrease, or stay the same as the cabinet slows to a stop?

Q3. Draw an energy diagram for the filing cabinet sliding on the ground after it was released.

Read and complete Steps 5-8 in your Energy Book.

Q4. In a brief statement (no more than one sentence), describe how an object would move without friction.

Read Step 9 in your Energy Book.

Q5. Based upon your observation of the filing cabinet’s speed after it was released from the hand, did the kinetic energy increase, decrease, or remain constant?

Q6. Do you think the temperature (and therefore thermal energy) of the filing cabinet and ground would increase, decrease, or stay the same? What is your reasoning?

Q7. Why do objects that have already been put into motion move at a constant speed when there is no friction? Use your responses to the previous two questions to help write your explanation.
### E.3 Summarizing Questions

<table>
<thead>
<tr>
<th>SUMMARIZING QUESTIONS</th>
<th>MY ANSWERS</th>
<th>ADDED IDEAS FROM THE READING</th>
</tr>
</thead>
<tbody>
<tr>
<td>In this activity, you considered a child who was sliding down on a Slip ‘N Slide® with water and without water. In each situation, all of the kinetic energy is transferred from the child.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. a. What evidence supports the idea that all of the kinetic energy is transferred from the child?

   b. In terms of energy transfer describe why the child is only injured in the situation without the water.

   c. Where does the energy go in the situation with and without water?

2. Compare how the Slip ‘N Slide® situation is similar to cars with and without a crumple zones.

   a. Discuss in terms of rate of change of velocity.

   b. Discuss in terms of energy transfer.

3. Consider the video showing the collision between the 2009 Chevy Malibu and the 1969 Chevy Bel Air. There was a test dummy in the driver seat of each car and each car was traveling at approximately the same speed prior to the collision.

   a. Make a claim about the kinetic energy of each test dummy prior to the collision.

   b. What can you say about the kinetic energy of each test dummy after the collision?

   c. Make a claim about which passenger (represented by each test dummy) would be the most injured based upon the rate at which they each slowed down?
2. What inferences can you make about energy from observing an object’s temperature increasing over time?

3. When an energy conversion occurs because of friction, does only one of the objects increase in thermal energy or do both objects increase in thermal energy? Give evidence from this activity.

4. Summarize the No Transfer-No Change idea in your own words.

5. Draw two velocity-time graphs: one for a cart that slows down quickly (has a greater rate of change of speed) and another for a cart that slows down slowly (has a smaller rate of change of speed). Describe the differences between the graphs.

6. Define the term negligible in your own words.
E.3 SCIENTISTS’ IDEAS READING

Instructions: As you read the Scientists’ Ideas, think about how they relate to the evidence you collected in the activity.

---

E.3a Friction and thermal energy: When objects in contact slide past each other, the friction causes kinetic energy to convert into thermal energy. The objects’ temperature increases, so you can infer the thermal energy increases.

E.3b Energy can be converted: Energy can be converted from one form to another. For example, kinetic energy can be converted into thermal energy as an object slows down.

---

When an object slows down due to friction, kinetic energy is converted to thermal energy between the object and the surface. You can sometimes feel this energy conversion when the temperature of the object and the surface increase. This warming-up is an increase in thermal energy. Evidence of an increase in thermal energy is an increase in temperature. The increase in thermal energy for both the object and the surface comes from the decrease in kinetic energy of the object that is slowing down.

---

E.3c Negligible friction: If the amount of friction is small enough, then you can ignore its effects when analyzing a situation. When something is small enough to be ignored, it is considered negligible.

---

Friction can never be totally eliminated, but its effects can sometimes be ignored in order to simplify the problem. Scientists say that friction is negligible when they know it is present, but it is so small in comparison to the other pushes and pulls that it can be ignored.

---

E.3d No transfer-no change: Without energy transfer, due to friction or any other source, an object that is moving will continue to move at constant speed since the kinetic energy is not changing.

Since it isn’t possible to completely remove friction, you made observations of a “frictionless” environment using the computer simulator. Without friction or any other source of energy transfer (such as pushes and pulls), energy was not transferred and the filing cabinet moved at a constant speed once the initial push stopped.
Rate: Rate is a term used to describe changes that happen over time. On a velocity-time graph, the rate of change of velocity (how quickly the object speeds up or slows down) is shown by the steepness of the line.

In the Summarizing Questions of this activity you thought about motion and energy transfer for a child on a Slip ‘N Slide®. You compared the motion of a child sliding on a Slip ‘N Slide® covered with water to one that was not covered with water. Without water, the child slows down very quickly. Scientists would say that the child slows down at a greater rate when the Slip ‘N Slide® is not covered with water.

The line on the velocity-time graph for the child sliding without water is steeper than the child sliding with water. We can see this because the child without water stops in 2 seconds whereas the child sliding with water stops in 10 seconds.

The steepness of the line on the velocity-time graph shows the rate of change of velocity and is also referred to as the slope.

Since the child slows down so quickly, you can infer that the kinetic energy also decreases quickly. This causes the thermal energy to increase very quickly and the child to receive a “burn.” This is how rug burn occurs. When there is water on the plastic sheet, the child only slows down a very small amount, so the increase in thermal energy is also very small.

Remember! Scientists use arrows, called vectors, to represent speed and the direction of motion. Vectors are labeled using a symbol with an arrow above it. (Key Idea E.1c: Vectors)

The motion of the child on the Slip ‘N Slide® can also be represented with velocity vector arrows. The term vector is used when information about both the direction and magnitude (size) is given. In the diagram on the right, the velocity arrows are drawn above the object. The direction of the arrow indicates the direction the object is moving and the length of the arrow represents the speed of the object. The symbol $|\vec{v}|$ is used to indicate the magnitude of the velocity (the speed), which is always positive.
Respond to the following questions **individually** in your lab notebook:

1. Provide an example of friction when you observe (feel) the increase in temperature of one or both of the objects.
2. What inferences can you make about energy from observing an object’s *temperature* increasing over time?
3. When an energy conversion occurs because of friction, does only one of the objects increase in thermal energy or do both objects increase in thermal energy? Give evidence from this activity.
4. Summarize the *No Transfer-No Change* idea in your own words.
5. Draw two velocity-time graphs: one for a cart that slows down quickly (has a greater rate of change of speed) and another for a cart that slows down slowly (has a smaller rate of change of speed). Describe the differences between the graphs.
6. Define the term **negligible** in your own words.
7. Provide two different examples when friction can be considered **negligible**.
8. Think about a cart given a quick push by a hand. After the hand lets go, friction slows the cart down. Draw a chain transfer energy diagram for the energy transfers/conversions that happen in this scenario.

![Energy Transfer Diagram](image)

9. Think of a situation that involves a chain energy transfer. Describe the situation and then draw an energy diagram for the energy transfers/conversions that happen.
10. Use ideas about energy transfer to describe why *rug burn* occurs if you slide across a carpet floor.
Apply physics principles developed in the activity by grappling with the questions below.

1. In this activity, you considered a child who was slowing down on a Slip ‘N Slide® with water and without water. In each situation, all of the kinetic energy is transferred from the child.

   ![Image of a child on a Slip 'N Slide](image1.png)

   a. What evidence supports the idea that all of the kinetic energy is transferred from the child?

   b. In terms of energy transfer describe why the child is only injured in the situation without the water.

   c. Where does the energy go in the situation with and without water?

2. Compare how the Slip ‘N Slide® situation is similar to cars with and without a crumple zones.

   a. Discuss in terms of rate of change of velocity.

   b. Discuss in terms of energy transfer.

3. Consider the video showing the collision between the 2009 Chevy Malibu and the 1969 Chevy Bel Air. There was a test dummy in the driver seat of each car and each car was traveling at approximately the same speed prior to the collision.

   ![Graph showing velocity-time for a child on a Slip 'N Slide](image2.png)

   a. Make a claim about the kinetic energy of each test dummy prior to the collision.

   b. What can you say about the kinetic energy of each test dummy after the collision?

   c. Make a claim about which passenger (represented by each test dummy) would be the most injured based upon the rate at which they each slowed down?
PURPOSE:
In previous activities, you made inferences about energy transfers between rigid objects (objects like carts that don’t bend or stretch). You observed speed increases and inferred that kinetic energy also increased and you observed speed decreases and inferred that kinetic energy also decreased. Unlike the carts, elastic objects (such as a rubber band or a trampoline) can be stretched or deformed in some way. How do these elastic objects change energy when they are in contact with other objects? How are energy transfers for elastic objects different than for rigid objects?

Key Question: What happens to energy when elastic objects interact with other objects?
INITIAL IDEAS:
Think about a child that is playing with a small slingshot, a toy made out of a stick and a rubber band. The child is launching little marshmallows across a field by pulling back the slingshot and then releasing the marshmallow.

Complete the following questions individually in your lab notebook:
1. Consider the time when the slingshot is being pulled back.
   a. What energy transfers are taking place?
   b. What energy conversions are taking place?

2. Consider the time when the marshmallow is released from the slingshot.
   a. What energy transfers are taking place?
   b. What energy conversions are taking place?

3. Would the slingshot work the same if the rubber band were replaced with string?
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Claim: What did we figure out?</th>
<th>Evidence: What did we do?</th>
<th>Self-Assess: Where am I with my understanding?</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1: Can energy be “stored” and used later? (How?)</td>
<td>Answer the experimental question. Summarize key information.</td>
<td>Summarize activities with a description and/or picture.</td>
<td></td>
</tr>
<tr>
<td>#2: What happens to energy when elastic objects are involved in a collision?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3: What happens to the total energy of the system?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Math Notes

#### Key Question
What happens to energy when elastic objects interact with other objects?

#### Phenomenon
In a car crash, energy enters the car-passenger-system and the passenger-system. How are these quantities different in older and newer cars?

#### What questions do I have?
What additional information do you need to understand the phenomenon?
EXPERIMENT #1: CAN ENERGY BE “STORED” AND USED LATER?

Step 1: Place the elastic launcher at one end of the table. You may either clamp the launcher to the table, have a group member hold it, or secure it with books.

Step 2: Use the cart to pull the elastic band back approximately 5 centimeters. See Video Here

Q1. Predict if there is energy in the elastic band when it is stretched back. Describe your reasoning.

Q2. Predict if there is energy in the cart at this time. Describe your reasoning.

Step 3: Release the cart and make observations of the motion of the cart and the behavior of the band.

Q3. Make a claim about where/how the cart got its kinetic energy. Support your claim with evidence.

Step 4: In your lab notebook, complete the statements below about how an elastic object’s energy changes, using the words increasing, decreasing, or staying the same.

- When an elastic object is being stretched, the amount of energy “stored” in the elastic is _______________________________.
- When an elastic object is being released, the amount of energy “stored” in the elastic is _______________________________.

Step 5: In your laboratory notebook, complete an energy diagram for when the elastic band launches the cart.

Step 6: Using the motion sensor, you will determine the maximum speed of the cart when it is
launched from a band that is stretched to different distances. Read the Tools of the Trade reading (below) about finding maximum speed from a velocity-time graph.

To find the **maximum speed** from a velocity-time graph, find the largest magnitude of velocity. You may ignore the negative sign because it is only telling you direction.

The graph on the right shows two carts. Cart A has a maximum speed of 20 cm/s and Cart B has a maximum speed of 30 cm/s. Cart B has a greater maximum speed than Cart A.

*Step 7: Copy the data table (on the right) into your laboratory notebook.*

Q4. Predict which stretch distance will result in the greatest maximum speed for the cart. Mark your prediction with a star in your data table.

<table>
<thead>
<tr>
<th>Stretch Distance (cm)</th>
<th>Maximum Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 cm</td>
<td></td>
</tr>
<tr>
<td>4 cm</td>
<td></td>
</tr>
<tr>
<td>8 cm</td>
<td></td>
</tr>
</tbody>
</table>

*Step 8: Do the following for each of the stretch distances listed in the table.*

- Use the cart to pull back the band so that when you release the cart, the band pushes the cart along the track.
- Use the ruler to measure how far you pull the band back.
- Using the motion sensor, collect maximum speed data when the cart is released.
- Complete the data table.

[See video here](#)

Q5. Make a claim about the stretch distance when the cart had the most kinetic energy (after being released). What evidence supports your claim?

Q6. Make a claim about the stretch distance when the band had the greatest amount of energy? What evidence supports your claim?

*Step 9: Look back to your initial ideas about the child who launched a marshmallow using a slingshot.*

Q7. What were your initial ideas about the energy transfers that occurred?
Q8. What would you change about your initial ideas and what new ideas could you add to your initial idea?

Q9. What evidence either supported your initial ideas or caused you to change it?
EXPERIMENT #2: WHAT HAPPENS TO ENERGY WHEN ELASTIC OBJECTS ARE INVOLVED IN A COLLISION?

Step 1: Place the elastic launcher at one end of the table. You may either clamp the launcher to the table, have a group member hold it, or secure it with books.

Step 2: Place the cart 20-30 cm away from the launcher. Start collecting velocity-time data and then give the cart a gentle push toward the elastic band.

See Video Here

Step 3: Discuss with your group members when the graph shows the kinetic energy of the cart decreasing, increasing, and zero.

Q1. Draw a chain energy diagram for the time when the cart is slowing down and then speeding up again.

![Energy Diagram]

Remember, when energy changes from one form of energy into a different form of energy, it is called an energy conversion. When energy moves from one object to another object, it is called an energy transfer.

Step 4: In your lab notebook, complete the statements below about energy transfers and conversions.

- When the cart is slowing down, energy is transferred from the _________________ to the ________________. During this time, energy is changing from ________________ energy to ________________ energy.

- When the cart is speeding up, energy is transferred from the _________________ to the _______________. During this time, energy is changing from ________________ energy to ________________ energy.

Step 5: Your instructor will show you a slow motion video of the cart when it collides with the elastic band. Below are pictures taken from the video at five different times.

See Video Here
Q2. When was the kinetic energy of the cart the greatest? When was the kinetic energy of the cart the least? What evidence supports your inferences?

Q3. When was the energy of the elastic band the greatest? When was the energy of the elastic band the least? What evidence supports your inferences?
EXPERIMENT #3: WHAT HAPPENS TO THE TOTAL ENERGY OF THE SYSTEM?

Step 1: The graphs shown below indicate when the cart first came in contact with the band (at 1.2 seconds) and when the cart was released from the elastic band (at 1.4 seconds). Use the graphs to answer the questions below.

Q1. What was the speed of the cart the moment it first came into contact with the elastic band (at 1.2 seconds)?

Q2. What was the speed of the cart the moment it was released from the elastic band (at 1.4 seconds)?

Q3. At 1.2 seconds and 1.4 seconds, does the elastic band have any energy? Describe your reasoning.

Q4. The energy in the cart/band system decreased from 1.2 seconds to 1.4 seconds, where do you think it went? Describe your reasoning.
Q5. As described in the Tools of the Trade reading, consider the system to be the cart and elastic band.
   a. When did energy enter the system? Where did it come from?

   b. Did energy leave the system during the time when the cart was in contact with the elastic band? What evidence supports your idea?

   c. Did energy leave the system at any other time after the cart was released from the hand and before the cart stopped? What evidence supports your idea?

Q6. At 1.3 seconds do you think that the energy within the system is mostly in the cart or mostly in the band? Describe your reasoning.

Q7. Write a mathematical equation that includes the following: o Energy that entered the system. o Energy that stayed in the system. o Energy that was transferred from the system to the surroundings.

   • The amount of energy that entered the system from the hand was _____________________ than the amount of energy that was in the system after the cart hit the band.
   • Energy was transferred from the cart/band _____________________ to the _____________________ in the form of thermal energy and sound energy.

Step 2: In your lab notebook, complete the statements below about the system and surroundings.

   ▪ The amount of energy that entered the system from the hand was _____________________ than the amount of energy that was in the system after the cart hit the band.
   ▪ Energy was transferred from the cart/band _____________________ to the _____________________ in the form of thermal energy and sound energy.
### E.4 Summarizing Questions

<table>
<thead>
<tr>
<th>SUMMARIZING QUESTIONS</th>
<th>MY ANSWERS</th>
<th>ADDED IDEAS FROM THE READING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What evidence supports the claim that elastic objects can &quot;store&quot; energy?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Graph of velocity-time](image1)

The graph on the right shows the velocity of a cart that was pushed toward an elastic band and then reversed direction due to contact with the band.

a. Circle and label the entire time the hand was in contact with the cart.
b. Circle and label the entire time the cart was in contact with the band.
c. Place an X on the graph at the moment when the band was stretched the most. What is your reasoning?
d. The graph below shows the kinetic energy for the cart. On the graph on the right, draw the elastic energy of the band.

![Graph of KE and Elastic Energy](image2)

3. Think again about a cart that is given a quick push and then gradually slows down due to friction. The graph of this cart’s motion (on the right) is labeled with the cart’s energy at different times. The system is only the cart.

![Graph of velocity-time on a track](image3)

![Energy diagram](image4)

a. Fill in the energy diagram below with the amount of energy that entered the system, stayed in the system, and left the system.
b. Write an equation that includes the following:
   - Energy that entered the system.
   - Energy that stayed in the system.
   - Energy that left the system.
4. Consider a cart that hits an elastic band. What would you expect would happen to the cart’s speed if the elastic band broke at exactly the moment when it is stretched the farthest? Describe your reasoning in terms of energy, system, and surroundings.
2. What evidence supports the claim that the more an elastic object is stretched, the more energy it is able to transfer to other objects?

3. Why do we say that objects with elastic potential energy or chemical potential energy are “storing” energy?

4. Consider a situation where a cart collides with an elastic band and then reverses direction. When the kinetic energy of the cart decreases, the elastic potential energy ________________, and when the kinetic energy of the cart increases, the elastic potential energy ________________.

5. The graph on the right shows the velocity of a cart that was pushed toward an elastic band and then reversed direction when coming in contact with the band.
   a. Label when the kinetic energy of the cart is increasing and when it is decreasing.
   b. Label when the elastic potential energy of the band is increasing and when it is decreasing.
   c. Label when the chemical potential energy of the hand is decreasing.
E.4 SCIENTISTS’ IDEAS READING

Instructions: As you read the Scientists’ Ideas, think about how they relate to the evidence you collected in the activity.

<table>
<thead>
<tr>
<th>E.4a</th>
<th>Elastic potential energy: When elastic objects are stretched they are able to store energy. This energy is called elastic potential energy and it is available as the object goes back to its unstretched position.</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.4b</td>
<td>Amount of elastic potential energy: The amount of elastic potential energy in an object increases as it is stretched.</td>
</tr>
</tbody>
</table>

Have you ever jumped on a trampoline and wondered why you are able to jump so much higher on a trampoline than when you are just jumping from the ground? This is because elastic potential energy is stored in the trampoline when it is stretched. When a person jumps on a trampoline energy is converted from one form to another: kinetic energy associated with the person’s speed is converted into elastic potential energy as the person lands on the trampoline and the trampoline is stretched. Then, as the trampoline goes back to its original position (becomes less stretched), the person is launched upward as elastic potential energy is converted back to kinetic energy.

The amount of elastic potential energy available increases as the object is stretched. For example, the further the jumper stretches the trampoline, the more elastic potential energy is stored.

Remember! Energy can be converted from one form to another. (Key Idea E.3b: Energy can be converted).

When energy is converted from elastic potential to kinetic, there is a decrease in elastic potential energy and an increase in kinetic energy. When kinetic energy is converted to elastic potential energy, there is a decrease in kinetic energy and an increase in elastic potential energy.

A velocity-time graph can show how the person’s speed changes throughout the jumping process on a trampoline.
System and surroundings: A system is one or more objects that you choose to focus on when talking about energy. The system idea is useful when you want to talk about the amount of energy that enters the system, the amount of energy that stays in a system, or the amount of energy that leaves a system. Everything outside of the system is the surroundings.

In this activity, you defined the system as the cart and the band. The graph on the right shows the motion of the cart when it hits the band and reverses direction. At 1.2 seconds and 1.4 seconds, the energy in the cart/band system is primarily in the cart as kinetic energy. At 1.3 seconds, the energy in the cart/band system is primarily in the band as elastic potential energy.

Only a small amount of energy (thermal and sound energy) is transferred out of the system to the surroundings during the time when the cart is in contact with the band. We can make this inference because when the cart left the band at 1.4 seconds, it was traveling at a slightly slower speed (0.426 m/s, compared to 0.471 m/s when it initially hit the band).

Law of Conservation of Energy: The total amount of energy in the universe always stays the same; energy is conserved. Even though you can talk about an energy leaving a system, it does not disappear—it goes into the surroundings.

The amount of energy that enters the system is equal to the amount of energy that stays in the system plus the amount of energy that leaves the system.

In other words, energy is always conserved. This means that all of the energy cannot be created and cannot disappear. It can, however, be converted from one form to another or transferred from one object to another. When an object gains energy, the energy does not just appear out of nowhere, it is converted or transferred from another object. When a cart is pushed by a hand, if the cart were considered the system, you could say that cart entered the system from the hand (which is part of the surroundings).
Respond to the following questions individually in your lab notebook:

1. When a person jumps on a trampoline, how does her energy change? What types of energy transfers and conversions take place?

2. What evidence supports the claim that the more an elastic object is stretched, the more energy it is able to transfer to other objects?

3. Why do we say that objects with elastic potential energy or chemical potential energy are “storing” energy?

4. Consider a situation where a cart collides with an elastic band and then reverses direction. When the kinetic energy of the cart decreases, the elastic potential energy ________, and when the kinetic energy of the cart increases, the elastic potential energy ____________.

5. The graph on the right shows the velocity of a cart that was pushed toward an elastic band and then reversed direction when coming in contact with the band.
   a. Label when the kinetic energy of the cart is increasing and when it is decreasing.
   b. Label when the elastic potential energy of the band is increasing and when it is decreasing.
   c. Label when the chemical potential energy of the band is decreasing.

6. Describe the differences between collisions that involve rigid objects and collisions that involve elastic objects.

7. The graph on the right shows a cart that was given a push and then slowed down due to friction while moving along the track. Define the system as the cart.
   a. When is energy entering the system? What is your reasoning?
   b. When is energy leaving the system? What is your reasoning?
EXPLORATION #1: WHAT IS A PROPORTIONALITY RELATIONSHIP?
Discuss each of the following questions with your group and respond in your lab notebook.

**Step 1:** Imagine that you are purchasing songs on the internet. Each song costs the same amount. You buy 1 song.

Q1. How many songs could you buy if you double the amount of money you are willing to spend?

Q2. Your friend is willing to spend three times as much money as you. How many songs can your friend buy?

Q3. Draw a graph that shows the amount of money you spend (Y-axis) and the number of songs you can buy (X-axis).

Q4. Use words to describe the relationship between these two variables. Discuss your description with another group.
Scientists use the term **proportional** to describe the relationship you have been investigating. A familiar example of this type of relationship is the distance traveled and time for a car moving at a constant speed: when time doubles, so does the distance. When time is multiplied by some number, the distance is also multiplied by that same number. We say that distance traveled is proportional to time for a car moving at a constant speed.

Scientists use the symbol \( \propto \) to represent a proportionality relationship. The symbol \( \propto \) means "proportional to."

In the car example, the relationship between distance traveled and time for a car that moves at a constant speed can be written as:

\[ \text{distance traveled} \propto \text{time} \]

Q5. Use the proportionality symbol to rewrite the relationship between the amount of money spent and the number of songs.

It is much more useful to know the *exact* relationship between the amount of money spent and the number of songs bought.

1 song costs $0.99

Because now the relationship is fully known, the \( \propto \) can be replaced by the equal sign (=):

\[ \text{Amount of money spent} = 0.99 \times \text{number of songs bought} \]

Q6. How much money did your friend (who spent three times as much as you) spend?

Q7. Discuss with your lab group the difference between the proportional sign (\( \propto \)) and the equal sign (=). Summarize the difference in your lab notebook.

Scientists often use **proportional relationships** to describe how certain variables depend on others. You will be using proportional relationships throughout this class.

Q8. Summarize the meaning of a proportional relationship. Include a new example.
EXPLORATION #2: WHAT INFLUENCES KINETIC ENERGY?
Discuss each of the following questions with your group and respond in your lab notebook.

Step 1: You are going to determine the relationship between mass and kinetic energy. Three wind-up cars with different masses travel at 1 m/s. By holding speed constant, you can find how mass influences the kinetic energy.

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>Velocity (m/s)</th>
<th>KE (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Q1. What patterns do you see in these data?

Q2. What happens to the KE of the car as its mass is doubled (multiplied by two)? As its mass is multiplied by three?

Q3. What do you expect should be the KE for a 4.0 kg car moving at 1 m/s?

Q4. What mathematical relationship can you use to represent this pattern? Check with another group to see if everyone in your lab group arrived at similar answer.


Q5. Explain why an equal sign can NOT be used in previous question.

Q6. Use your mathematical relationship to find the kinetic energy of a 5 kg car traveling at 1 m/s.

Step 2: You are going to determine the relationship between velocity and kinetic energy. Three wind-up cars with the same mass travel with different velocities. By holding mass constant you can determine how velocity influences the kinetic energy.

Q7. You saw before that when the mass is doubled, the KE also doubled. Does the KE double when the velocity is doubled?
Q8. Is the relationship between \( v \) (NOT \( v^2 \)) and KE a proportionality relationship? Describe your rationale.

Q9. What is the relationship between \( v^2 \) and KE? Describe your rationale.

Q10. Using a proportionality symbol (\( \propto \)), write the mathematical relationship between KE and \( v^2 \). Check with another group to see if everyone in your lab group arrived at similar answer.

\[ KE \propto \ldots \]

Step 3: Now, combine the two relationships that you have just discovered (the relationship between KE and \( v \) and the relationship between KE and \( m \) from the previous steps).

---

Scientists have determined that mass and velocity are the only two variables that affect kinetic energy. Since we know all the variables involved in the relationship, the equals sign can now be used to write an equation. The kinetic energy of an object is equal to the \( \frac{1}{2} \) times the mass and velocity squared.

\[ KE = \frac{1}{2} mv^2 \]

Remember that mass is measured in kilograms (kg) and velocity is measured in meters per second (m/s). Kinetic energy, like all forms of energy, is measured in Joules (J).

Step 4: Use the equation for kinetic energy to calculate the kinetic energy of the object in the questions below. Check your results with the data on table 1.

Q11. What is the kinetic energy of a 1 kg object traveling at 4 m/s?

Q12. What is the kinetic energy of the same object (1 kg) traveling at 8 m/s?
**MATHEMATICAL MODELS: PRACTICE**

_respond to the following questions in your laboratory notebook. Show your work._

**Support Questions:** The first three questions include fill-in-the-blank supports to help you learn how to set up the problems. If you already feel comfortable solving these problems, consider trying to solve them without using the fill-in-the-blank supports. You can check your work using the supports.

1. A boy throws a 0.5 kg ball to his sister at 4 m/s. What is the KE of the ball at this speed?
   
   **Optional Fill-in-the-Blank Supports**
   
   \[
   KE = \frac{1}{2} \text{mv}^2
   \]
   
   \[
   KE = \frac{1}{2} (\text{m})(\text{v})^2 = \text{___}\text{ Joules}
   \]

2. The boy’s sister catches the ball and throws it back to him at 10 m/s. What is the KE of the ball at this speed?
   
   \[
   KE = \frac{1}{2} \text{mv}^2
   \]
   
   \[
   KE = \frac{1}{2} (\text{m})(\text{v})^2 = \text{___}\text{ Joules}
   \]

3. The boy then throws a ball with twice the mass, 1.0 kg, at 5 m/s. What is the KE of the ball at this speed?
   
   \[
   KE = \frac{1}{2} \text{mv}^2
   \]
   
   \[
   KE = \frac{1}{2} (\text{m})(\text{v})^2 = \text{___}\text{ Joules}
   \]

4. Would you double the mass or double the speed if you wanted to increase the KE the most? What relationships support your answer?

5. What is the kinetic energy of a car that is 750 kg and is moving at 14 m/s?

6. If a sprinter runs at a speed of 10.4 meters per second and has a mass of 90 kilograms, what is the sprinter’s kinetic energy?

7. A roller coaster cart has a mass of 300 kg. When it is moving at its maximum speed of 38 meters per second (this is 85 miles per hour!), what is its kinetic energy?

8. Six people get into the roller coaster cart (from the previous question). The total mass of these people is 400 kilograms. When moving at its maximum speed, what is...
of 38 meters per second (this is 85 miles per hour!), what is its kinetic energy?

8. Six people get into the roller coaster cart (from the previous question). The total mass of these people is 400 kilograms. When moving at its maximum speed, what is the kinetic energy of the cart with six people in it?

9. Make a claim about whether the direction an object is traveling influences the kinetic energy: towards (negative $\vec{v}$) or away (positive $\vec{v}$)? Explain in terms of the equation for kinetic energy.

---

10. In Experiment #1 of E.4, you found the maximum speed of a cart when it was launched from an elastic launcher (different stretch distances). Use your data from Experiment 1 to calculate the kinetic energy of the cart when it was released at each stretch distance. The mass of the cart is approximately 250 grams (0.25 kg). Complete a table like the one shown on the right in your lab notebook.

<table>
<thead>
<tr>
<th>Stretch Distance (cm)</th>
<th>Maximum Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 cm</td>
<td></td>
</tr>
<tr>
<td>4 cm</td>
<td></td>
</tr>
<tr>
<td>8 cm</td>
<td></td>
</tr>
</tbody>
</table>

Challenge Yourself! These problems are about the same mathematical ideas, but are more challenging. Respond to them in your lab notebook and show your work.

1. An aircraft carrier has a mass of about 5 x 10$^8$ kg (about 100,000 tons). What is the KE of an aircraft carrier cruising at 5 m/s (about 11 miles per hour)?

2. A ski boat has a mass of about 1,500 kg (around 3,000 pounds). What is the KE of a ski boat traveling at 5 m/s?

3. If the ski boat in the previous question has the same KE as the aircraft carrier, how fast is it moving?

4. If you had information about the kinetic energy and the speed of an object, how could you rearrange the equation for kinetic energy in order to calculate the mass of the object?

5. If you had information about the kinetic energy of an object and the mass of that object, how could you rearrange the equation for kinetic energy in order to calculate the velocity of the object?

6. Complete the table (shown below) in your laboratory notebook.

<table>
<thead>
<tr>
<th>Mass</th>
<th>Velocity (v)</th>
<th>KE</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 kg</td>
<td>1 m/s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 m/s</td>
<td>18 J</td>
</tr>
<tr>
<td>6 kg</td>
<td>1 m/s</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>3 m/s</td>
<td>18 J</td>
</tr>
<tr>
<td>20 kg</td>
<td></td>
<td>160 J</td>
</tr>
</tbody>
</table>

7. In January 2012, an asteroid passed between the Earth and the Moon. If the asteroid had a mass of 100,000,000 kg and a KE of $2.42 \times 10^{16}$ Joules, what was its speed?

8. An asteroid had an estimated mass of at least $9 \times 10^{10}$ kg and struck the Earth at 11,000 m/s, killing off up to 70% of all species on Earth. What was the KE of the asteroid?

9. A World War II era nuclear bomb can release up to $7.5 \times 10^{13}$ Joules (750,000,000,000,000 Joules). How many of these bombs would equal the energy released by the asteroid impact from the previous question?
Apply physics principles developed in the activity by grappling with the questions below.

Before answering these questions, you may find it helpful to re-watch the crash test between the 2009 Chevy Malibu and the 1969 Chevy Bel Air:
https://www.youtube.com/watch?time_continue=72&v=C_r5Ujrxck

1. There are many different ways you could define the system and surroundings in the situation of the collision between the 2009 Chevy Malibu and the 1969 Chevy Bel Air. One example is provided below. List two other ways that you could define the system and surroundings for this collision.

<table>
<thead>
<tr>
<th>System</th>
<th>Surroundings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old car (1969 Chevy Bel Air)</td>
<td>Everything else (new car, test dummy in old car, test dummy in new car, environment around the cars)</td>
</tr>
</tbody>
</table>

2. Select one of your system-surroundings choices from Question 1. Place a star next to the system-surroundings definition you selected and then answer the questions below.

   a. Summarize the energy transfers into the system. What evidence from the video supports your claim?

   b. Summarize the energy transfers out of the system. What evidence from the video supports your claim?

3. One way of defining a system is the passengers in each car. This is shown in the diagram below:

   a. How does the energy entering into System A compare to the energy entering into System B? Describe your reasoning.

   b. Would you say that there is more energy “absorbed by” the front of the new car or by the front of the old car? Describe your reasoning.

   c. If energy is not transferred from the car into the system (crash test dummy), where does it go?

4. Given that you are trying to evaluate the safety of a car in terms of energy transfers and conversions, what system from the list below would be most useful? Describe your reasoning.

   - System A
   - System B
<table>
<thead>
<tr>
<th>System</th>
<th>Surroundings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1 engine in the old car</td>
<td>Everything else</td>
</tr>
<tr>
<td>Option 2 passenger in old car</td>
<td>Everything else</td>
</tr>
<tr>
<td>Option 3 old car + passenger in old car</td>
<td>Everything else</td>
</tr>
<tr>
<td>Option 4 old car + new car</td>
<td>Everything else</td>
</tr>
</tbody>
</table>
1. The Popular Mechanics excerpt above discusses two different ways that kinetic energy can be dispersed when a car slows down: by hitting the breaks or by hitting something.
   a. Discuss the energy transfers and conversions that occur when a car slows down by hitting the breaks. Draw an energy diagram to support your response.

   b. Discuss the energy transfers and conversions that occur when a car slows down by hitting something. Draw an energy diagram to support your response.

   c. Imagine defining the system as the car itself. In each situation, describe when and how energy leaves the system.

      Hitting the breaks:

      Hitting something:

2. Imagine a car accident where the driver slams on the breaks to slow the car from 70 miles per hour to 30 miles per hour before the car collides with a brick wall.
   a. Draw a velocity time graph that shows the motion of the car during the entire scenario described above.

   ![Velocity-Time Graph](image)

   b. Summarize the energy transfers and conversions that take place from the time when the driver slams on its brakes to the time when the car collides with the brick wall. Assume that the driver is in a newer model car with crumple zones.
3. How would your responses to the previous question change if the driver was in an older model car that did not have crumple zones? Describe your reasoning.