2 *Measuring and Graphing Speed*

LABORATORY

2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students use a model cart system to measure the time that it takes for a cart to travel a certain distance, and they use their results to calculate speed—a rate, or proportional relationship. They analyze and interpret motion graphs, and they identify that the slope of the motion graph represents the speed of an object at a given point in time. They learn the importance of a reference frame when quantitatively describing a moving object's speed and direction of motion.

NGSS CORRELATIONS

Performance Expectations

Working toward MS-PS3-1: Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Disciplinary Core Ideas

MS-PS3.A Definitions of Energy: Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.

Science and Engineering Practices

Analyzing and Interpreting Data:

Construct and interpret graphical displays of data to identify linear and nonlinear relationships.

Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).

Using Mathematics and Computational Thinking: Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

Crosscutting Concepts

Scale, Proportion, and Quantity:

Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Scientific relationships can be represented through the use of algebraic expressions and equations.

Patterns: Graphs, charts, and images can be used to identify patterns in data.

Common Core State Standards—Mathematics

7.RP.A.2: Recognize and represent proportional relationships between quantities.

Common Core State Standards—ELA/Literacy

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

INVESTIGATIVE PHENOMENA AND SENSEMAKING

Some car accidents cause more damage than others.

Students begin to explore one of the major factors involved in car accidents—speed—by becoming familiar with a cart and ramp system. They figure out how to quantify speed and represent speed graphically.

WHAT STUDENTS DO

Students use a cart, ramp, and track to measure the time it takes for a cart to roll 100 cm. They calculate speed from their distance and time measurements and express it as a rate of motion. Students then match segments of a distance-vs.-time graph to portions of a narrative describing two students' journeys to school. The graphs allow students to determine both the speed and the relative position of an object with respect to a fixed point.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Visual Aid 2.1a, "Graph of Teasha's Trip to School"
  - 1 Visual Aid 2.1b "Graph of Josh's Trip to School"
  - 1 Visual Aid 2.2, "Group Interactions Classroom Rubric" (optional)
  - 1 Scoring Guide: ANALYZING AND INTERPRETING DATA (AID) (optional)
  - * 16 paper clips or envelopes

- *For each group of four students*
  - 2 track pieces
  - 1 cart
  - 1 ramp
  - masking tape
  - * 1 meter stick
  - * 1 marker
  - * calculator
  - * 1 book or heavy object (optional)

If using the timer method for measuring speed

- 1 timer

If using the magnetometer method for measuring speed

- 1 smartphone holder with cart attachment
- 2 disk magnets
- 2 large rubber bands
- * 1 smartphone

- *For each pair of students*
  - 1 set of 8 strips cut from Student Sheet 2.1, "Trip Strips"
  - 1 Student Sheet 2.2, "Teasha's and Josh's Trips to School"
  - * 1 pair of scissors
  - * tape or glue

- *For each student*
  - 1 Scoring Guide: ANALYZING AND INTERPRETING DATA (AID) (optional)

* *not included in kit*

The ANALYZING AND INTERPRETING DATA (AID) Scoring Guide can be found in the Assessment tab in the back of this Teacher Edition.

For Part A, decide if students will use timers or magnetometers for measuring speed. To use magnetometers, each group will need a smartphone that has the free *Science Journal by Google* app loaded onto it.

For Part B, make enough copies of Student Sheet 2.1, "Trip Strips," so that each pair of students will have one set of A–H strips. Separate the four sets on each Student Sheet by cutting it into quarters. Procedure Step 10 instructs students to further cut apart those sets into eight strips, but you may want to do this in advance. For convenience, each set of strips can be held together with a paper clip or placed in an envelope.

TEACHING SUMMARY

GET STARTED

1. Support students' sensemaking by eliciting their ideas about vehicle accidents and speed.
   a. Build on students' experiences by asking them what factors can contribute to a vehicle accident.
   b. Have students read the introduction and the guiding question: How can you measure and graph the speed of a moving object?

DO THE ACTIVITY

2. If you have not previously done so, introduce the SEPUP model for collaborative work.
   a. Introduce SEPUP's 4–2–1 model for collaborative work.
   b. Clarify which situations are appropriate for collaboration and which are appropriate for working independently.
   c. Introduce strategies for effective group interactions.
   d. Explain how you will distribute materials.
3. Students conduct the investigation in Part A.
   a. Have students set up their track and data table.
   b. Ask students, "Why do you think you are asked to do three trials?"
   c. Show students how to measure the time it takes the cart to travel 100 cm, using either a timer or a smartphone.
   d. Circulate throughout the room as students conduct the investigation.
4. Students calculate speed in Procedure Step 7.
   a. Point out the equation for speed: speed = distance / time
   b. If you have not already done so, introduce the crosscutting concept of *scale, proportion, and quantity*.
   c. Ask students, "How does the crosscutting concept of *scale, proportion, and quantity* help us investigate speed?"
   d. Have groups share the average speeds they calculated, and compile them on the board.
   e. Direct students to Analysis item 1.
5. Students complete Part B of the Procedure: exploring motion graphs as a way to depict speed.
   a. Ask students, "When you measured the speed of a cart rolling down a track, do you think the cart was going the same speed the whole time?"

b. Let students know that they will analyze graphs of distance-vs.-time that show motion over a whole trip, as opposed to determining one average speed over a trip.

c. As a class, read the scenario and review the diagram of Josh's and Teasha's trips in the Student Book.

d. Introduce what a distance-from-home-vs.-time graph, a type of motion graph, looks like by sketching one on the board.

e. Distribute Student Sheet 2.2, "Teasha's and Josh's Trips to School," and direct students' attention to the graphs.

f. Have students complete Procedure Steps 11–14.

g. Discuss students' choices for matching the strips to the graph segments.

BUILD UNDERSTANDING

6. Students respond to Analysis items 2–5.

   a. (AID QUICK CHECK) Direct students to Analysis item 2.

   b. Discuss the meaning of slope on these types of motion graphs as a class. (optional)

   c. Explain that Analysis items 3–5 provide additional practice for students in analyzing and interpreting the motion graphs.

TEACHING STEPS

GET STARTED

1. Support students' sensemaking by eliciting their ideas about vehicle accidents and speed.

   a. Build on students' experiences by asking them what factors can contribute to a vehicle accident.

   Students may suggest that not paying attention, not stopping in time, and slippery road conditions can contribute to vehicle accidents. Make sure that speeding or driving fast is mentioned. Explore students' ideas of speed, using the units of measure described in the introduction and everyday examples. For example, in the United States, vehicle speed is typically measured in miles per hour (MPH), while most other countries use kilometers per hour (km/h) for car speed. Point out that scientists often measure everyday speeds in meters per second (m/s), but in this activity, students will measure speed in centimeters per second (cm/s).

   Elicit, Probe, and Challenge

   b. Have students read the introduction and the guiding question: How can you measure and graph the speed of a moving object?

   Ask students how they think speed is measured. If they respond with names of devices, such as speedometers or radar guns, ask them how people measured speed before those devices were invented. All speed-tracking devices, whether modern or not, measure the time that it takes to travel a distance. Guide students to understand that the basic method of measuring *speed* must involve measuring both time and distance.

This activity starts a sequence of learning around the second driving question (which is identified in the Phenomena, Driving Questions, and SEPUP Storyline overview): How can we predict the amount of impact of a car accident? Pose the question, and have students share their ideas.

DO THE ACTIVITY

2. If you have not previously done so, introduce the SEPUP model for collaborative work.

   a. Introduce SEPUP's 4–2–1 model for collaborative work.

4-2-1 Model

   Explain that many activities in this unit use the SEPUP 4–2–1 cooperative learning model. Students work in groups of four or in pairs to share, discuss, compare, and revise their ideas and to conduct investigations and activities. In all cases, each student is responsible for contributing ideas, listening to others, recording and analyzing their results, and monitoring their own learning.

   b. Clarify which situations are appropriate for collaboration and which are appropriate for working independently.

   In science, collaboration is essential for the development of new ideas and a better understanding of scientific concepts. However, scientists must publish only their own work and must give others credit when they build on their ideas.

   c. Introduce strategies for effective group interactions.

Facilitating Group Work

   Explain or model what productive group interactions (both agreement and constructive disagreement) look and sound like. Consider projecting Visual Aid 2.2, "Group Interactions Classroom Rubric" and reviewing it with students.

   d. Explain how you will distribute materials.

   The materials management reflects the 4–2–1 structure of the classroom activities. The equipment kit typically contains materials in either sets of 16 (for each pair of students in a class of 32 students) or 8 (to be shared among groups of 4), depending on how the activity is organized.

   You might wish to distribute the materials in numbered containers. This will allow you to quickly check the contents of the containers and hold groups accountable for ensuring that their materials are returned in good shape.

3. Students conduct the investigation in Part A.

   a. Have students set up their track and data table.

      Teacher's Note: Before students complete the Procedure, make sure that they have a way to prevent the cart from rolling off the track and falling to the floor. The cart will sustain damage and provide inconsistent results if repeatedly mishandled. Have students either place a book or other heavy object at the end of the track to prevent a runaway cart, or perform the experiment on the floor.

      Students should be able to follow the diagram in the Student Book to set up the track and ramp on their tables. Make sure that students position the track at least a few inches away from the edges of the table so that the cart is less likely to fall off the table. Students may need help placing the tape on their tables to mark the starting and finish lines. Explain that the two pieces of tape should be placed 100 cm apart.

   b. Ask students, "Why do you think you are asked to do three trials?"

      Students should have the sense that repeating a trial several times improves the quality of the data set, but have them try to articulate why this is. Help students understand that one trial might have an odd result because of errors, and doing more trials will give more reliable results.

   c. Show students how to measure the time it takes the cart to travel 100 cm, using either a timer or a smartphone.

      Procedure Step 4 in the Student Book instructs students to follow your instructions for how to measure time in this activity. There are two methods for doing this:

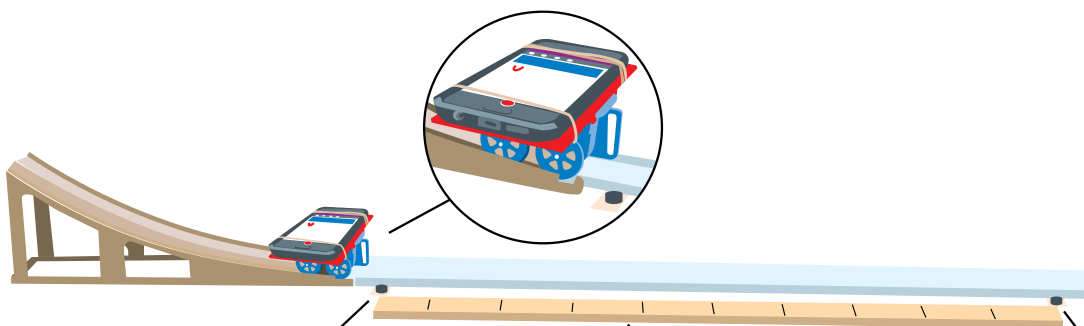
      The timer method: Students use a timer to visually start and stop, depending on when the front of the cart passes the starting and finish lines, respectively.

      Have students familiarize themselves with the timer's buttons. Students will need only to start, stop, and reset to complete this activity. Have one student from each group volunteer to be the timer, and ask them to position themselves so that they can easily observe when the cart crosses the starting and finish lines. Tell them that they should start the timer the moment the front of the cart reaches the starting line and then stop the timer the moment the front of the cart reaches the finish line. It is important that students follow this convention for each of their three trials. Let students know that if they make a mistake in starting or stopping their timers, they should do a make-up trial.

      The magnetometer method: Students use a smartphone with an app that can detect a magnet at the starting line and another magnet at the finish line. This method requires the equipment listed under this option in Materials and Advance Preparation. Refer to the diagram on the next page for the magnetometer setup. Have one student from each group volunteer to use their smartphone as the measuring device for this activity, and make sure that they have the *Science Journal by Google* application installed on their phone.

Pass out the additional materials, and ask students to slide the smartphone holder onto their cart. Caution students to handle the attached smartphone with care to avoid any damage to the phone. Have each group place one magnet on the starting line and one magnet on the finish line. Results are best if the two magnets have their north poles side up. Once students are ready to conduct their experiments, they should ensure that the smartphone is securely attached to the smartphone holder using two rubber bands and that the app has the magnetometer showing. Once ready, students should press the red recording circle on their app and release their cart down the track.

When the cart has crossed the finish line, students can stop data collection. To use the app to measure the time it took for the cart to travel between the two magnets, students can drag their finger from the first peak in their data to the second peak in their data, and note the times associated with each. The difference between the times recorded from each peak is the amount of time it took for the cart to travel the distance between the two magnets.



d. Circulate throughout the room as students conduct the investigation.

Students might notice that the cart slows down over the course of the track, and they may decide that this introduces errors in the experiment. If students raise this issue, point out that the cart should slow down consistently in each trial since the track is a controlled component of the experiment. Since the slowing is occurring across all trials, it is not a factor that will introduce noticeable errors in the data. If appropriate, briefly discuss the friction between the cart and the track, which is what slows the cart. Because *friction* is formally introduced later in the unit, it is sufficient at this point to merely identify it and its effects.

4. Students calculate speed in Procedure Step 7.

   a. Point out the equation for speed:

   speed = distance / time

   Write the equation on the board, and introduce or review its use by asking such questions as, "What is the speed of a vehicle that travels 100 miles in 2 hours?" (50 MPH), and "What is the speed of a vehicle that travels 30 km in 1/2 hour?" (60 km/h). Reinforce the idea that the forward slash (/) is read as "per" and means "divided by."

   b. If you have not already done so, introduce the crosscutting concept of *scale, proportion, and quantity*.

   Crosscutting Concepts

   Explain that crosscutting concepts bridge disciplines, and can be a lens or touchstone through which students make sense of phenomena and deepen their understanding of disciplinary core ideas.

   Refer students to Appendix G: Crosscutting Concepts in the Student Book, and point out the symbols and definitions provided. Review the symbol for *scale, proportion, and quantity*: a simple diagram of a number of squares of different sizes and proportions. Scientists use proportional relationships to compare measurements of objects and events. They often use mathematical expressions and equations to represent these relationships.

   Vocabulary Log

   You might use this point in the activity to have students keep a personal vocabulary log to keep track of new terms as they learn their meaning, beginning with the terms in this crosscutting concept.

   c. Ask students, "How does the crosscutting concept of *scale, proportion, and quantity* help us investigate speed?"

   Students should recognize that speed is a proportional relationship quantifying an amount of distance covered in a particular amount of time.

   d. Have groups share the average speeds that they calculated, and compile them on the board.

   Students should find that the cart takes between 1 s and 2 s to travel 100 cm, as shown by the sample data below. Results may differ depending on variations in the cart and track.

CART SPEED

Trial	Distance (cm)	Time (s)	Speed (cm/s)
1	*100*	*1.34*	*74.6*
2	*100*	*1.36*	*73.5*
3	*100*	*1.14*	*87.7*
		Average	*78.6*

If any group's results are significantly different but are consistent (e.g., all faster or all slower), try to determine the cause. If only a few times are really different, point these out, and discuss whether to discard these outliers as "bad" data or to keep them in the data set. Such outliers are most likely to arise from human error when the timer is started and stopped. Sometimes students want to discard the outliers. In either case, point out that although these times are significantly different, it doesn't necessarily mean that they are wrong.

e. Direct students to Analysis item 1.

This item will allow you to check if students can correctly calculate speed.

5. Students complete Part B of the Procedure: exploring motion graphs as a way to depict speed.

a. Ask students, "When you measured the speed of a cart rolling down a track, do you think the cart was going the same speed the whole time?"

Lead students to the understanding that the cart started at rest, a speed of 0 m/s, then sped up to its top speed, and eventually slowed down until it stopped and came to rest, once again having a speed of 0 m/s. Emphasize that when they measured the speed of the cart, they found its average speed over a distance of 100 cm (or 50 cm) on the flat part of the track. Distinguish this from *instantaneous* speed, or the speed at any given moment in time, as reflected on a speedometer.

b. Let students know that they will analyze graphs of distance vs. time that show motion over a whole trip, as opposed to determining one average speed over a trip.

The calculations students made in the first part of the activity used measurements from the end points (initial distance, final distance, and time interval), which gave no information about the speed in the middle of the trip. A cart could speed up and slow down and have the same average speed over the whole track as a cart that moved at a constant speed. Explain that a graph of distance vs. time is a powerful tool because it shows the motion at any moment of time during the whole trip.

c. As a class, read the scenario and review the diagram of Josh's and Teasha's trips in the Student Book.

Point out that the road from Josh's and Teasha's houses to the school is straight; thus, a trip directly to school wouldn't require any turning. This activity focuses on linear motion only, but because the graphs show changes as slopes or curves, students will likely think that the graphs show a change in direction (such as north, south, east, or west). To help dispel this misconception, remind students more than once during this activity that the graphs show what is happening during a trip on a straight road.

Teacher's Note: The motion graphs used in the Procedure are simplified to make them easier for students to analyze and interpret. There are points on each graph that would be problematic if these graphs were used to analyze acceleration; however, the graphs are not used for that purpose in this activity.

d. Introduce what a distance-from-home-vs.-time graph, a type of motion graph, looks like by sketching one on the board.

Point out that the vertical y-axis represents distance from the starting point, and the horizontal x-axis represents time. Define the slope of the line on the graph as a measure of its incline—the ratio of the change in y compared to the change in x. To get students thinking about how to interpret these graphs in the context of the activity, ask them to think about what each of the following means:

- A positive (upward) slope
- A zero slope (horizontal line)
- A negative (downward) slope

At this point in the activity, it is unlikely that students will have a firm understanding of slope, so accept all reasonable interpretations. This is a good time to check students' background knowledge about graph reading to give you an idea of how much help they might need as they do the activity. Let students know that they will explore how the slope on the graph relates to speed. Remind students of Interpreting Graphs in Appendix C of the Student Book to help them read and interpret the motion graphs. Eventually, students will be able to explain the following:

- A positive (upward) slope means that the vehicle is moving away from home.
- A zero slope (horizontal line) means that the vehicle has stopped.
- A negative (downward) slope means that the vehicle is moving back toward home.

e. Distribute Student Sheet 2.2, "Teasha's and Josh's Trips to School," and direct students' attention to the graphs.

Pass out the trip strips (or blocks of trip strips to be cut apart) to student groups, making clear to them that the letters on each strip are

Science and Engineering Practices

for identification purposes only and have nothing to do with the order of events. Point out that only two of the strips, E and F, identify whose trip those strips belong to. Let students know that they will be using the science and engineering practice of *using mathematics and computational thinking* as they carry out the procedure.

f. Have students complete Procedure Steps 11–14.

Circulate around the room, helping groups who are having difficulty matching the strips to the graph segments. You might tell them that Trip Strips C, D, and F are for Teasha's journey, and A, B, E, G, and H are for Josh's journey.

For Teasha's trip, the chronological order of the trip strips is D, C, F. For Josh's trip, the order is G, E, A, H, B.

g. Discuss students' choices for matching the strips to the graph segments.

Use Visual Aid 2.1a, "Graph of Teasha's Trip to School," and Visual Aid 2.1b, "Graph of Josh's Trip to School," to display the correct chronological order of the trip strips.

BUILD UNDERSTANDING

Quick Checks

Science and Engineering Practices

6. Students respond to Analysis items 2–5.

a. (AID QUICK CHECK) Direct students to Analysis item 2.

This Analysis item provides an opportunity to check students' ability to analyze and interpret motion graphs. Display or pass out the ANALYZING AND INTERPRETING DATA (AID) Scoring Guide, and tell students they will not be assessed using this Scoring Guide in this activity, but they will in a future activity. Point out how this guide has the same levels as other Scoring Guides but different descriptions for each level. Review the levels as needed. A sample Level 4 response can be found in the Sample Responses to Analysis. This scoring guide assesses students' ability to engage in the science and engineering practice of analyzing and interpreting data.

b. Discuss the meaning of slope on these types of motion graphs as a class. (optional)

If students are struggling to interpret the meaning of *slope* in this context, spend some time discussing this. Focus on the idea that the slope for a distance-vs.-time graph is equivalent to the speed of the object. Emphasize that steeper slopes mean faster speeds and that a horizontal line (0 slope) means that the object has stopped and has a speed of zero (0). Start by introducing or reviewing the equation for the slope of a line:

$$\text{slope} = \frac{\text{the change in y } (\Delta y)}{\text{the change in x } (\Delta x)}$$

Next, explain that since the *y*-axis is distance and the *x*-axis is time, the slope,

$$\frac{\Delta y}{\Delta x}$$

is actually the change in distance divided by the change in time, which is the formula for speed. The substitution can be shown as

$$\text{slope} = \frac{(\Delta y)}{(\Delta x)}$$

$$= \frac{\text{the change in the distance } (\Delta d)}{\text{the time interval } (\Delta t)}$$

c. Explain that Analysis items 3–5 provide additional practice for students in analyzing and interpreting the motion graphs.

If necessary, help students understand that downward sloping segments of the line indicate that the vehicle has reversed direction and is returning to a position closer to the starting point. Students commonly misinterpret a negative slope as a slowing down, so be sure to emphasize that the steepness of the slope is the speed of travel, and the direction of the slope indicates if its moving forward or backward. These items provide an opportunity to reinforce the idea that all the graphs in this activity only reflect linear motion.

Teacher's Note: The motion graphs used in Analysis item 5 are simplified to make them easier for students to analyze and interpret. There are points on each graph that would be problematic if these graphs were used to analyze acceleration; however, the graphs are not used for that purpose in this activity.

STRATEGIES FOR TEACHING DIVERSE LEARNERS

Below are suggestions for differentiating instruction and assessment in this activity for diverse learners in your classroom:

- Students with learning disabilities: Conduct the first speed trial as a whole class before instructing groups to conduct their own trials.
- Academically gifted students: Have students conduct additional trials and describe the spread of values around the mean.

SAMPLE RESPONSES TO ANALYSIS

1. What is a car's speed in m/s if it travels ...

   a. 5 m in 0.1 s?

   50 m/s

   b. 5 m in 0.2 s?

   25 m/s

   c. 10 m in 0.2 s?

   50 m/s

2. (AID QUICK CHECK) Identify a place on each motion graph where the following occurs:

   SAMPLE LEVEL 4 RESPONSE

   a. The line is flat. What does it mean when the slope of the line is zero?

   A flat line means that the car isn't moving. If the car were moving, then the distance would be changing over time. A line with a zero slope means that the y-axis isn't changing, and in this case, the y-axis is distance.

   b. The slope of the line changes. What does a change in the slope of a motion graph indicate?

   A change in the slope of the line means that the car is changing speed. When the line gets steeper, it means the car is covering a greater distance in a period of time. The car is going faster. When the line gets less steep, it means the car is covering a shorter distance in a period of time. The car is going slower.

3. Which student—Teasha or Josh—started out faster? Explain how you know this.

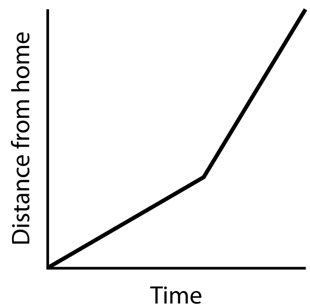
   Teasha started faster than Josh did. I know this because I looked at the graphs, and Teasha's has a steeper slope than Josh's. Her slope for the first segment is 0.5 miles/minute, and Josh's is 0.4 miles/minute. Since Josh's slope is less steep than Teasha's, he wasn't moving as fast.

4. How far into the trip did Josh turn around? Describe what the graph looks like at this point in the trip.

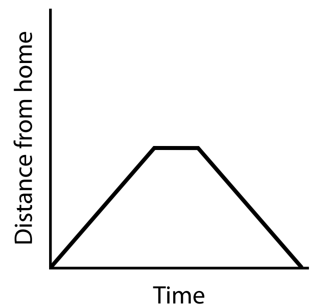
   Josh turned around 6 minutes after he left home—5 minutes traveling 2 miles and 1 minute stopped. You know this because from Minute 6 to Minute 10, the slope of the graph is negative (downward), which indicates a reversal in the direction of motion. With a positive (upward) slope, the distance away from the starting point increases with time. With a negative slope, the distance from the starting point decreases with time, which means that the car is getting closer to, or traveling back toward, the starting position.

5. Look at the following motion graphs that indicate distance vs. time. Match the descriptions here to the correct graphs.

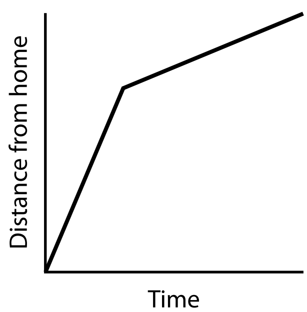
GRAPH 1



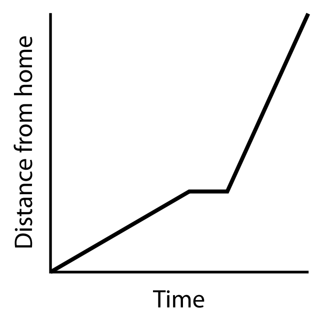
GRAPH 2



GRAPH 3



GRAPH 4



a. A car moving at a constant speed stops and then moves in the opposite direction at the same speed.

Graph 2

b. A car moving at a constant speed stops and then moves faster in the same direction.

Graph 4

c. A car moving at a constant speed changes to a higher constant speed.

Graph 1

d. A car moving at a constant speed changes to a lower constant speed.

Graph 3

EXTENSION 1

Have students post their results on the *SEPUP Third Edition Force and Motion* page of the SEPUP website at **www.sepuplhs.org/middle/third-edition**, and compare their data sets to those of students in other classes.

EXTENSION 2

Have students consider the following question: If the speed limit is 60 MPH, could the police give a speeding ticket to any of the drivers of the cars in Analysis item 1?

Hint: 1,000 m = 1 km = 0.62 miles

Because this problem requires some fairly complicated unit conversions, it may not be appropriate for all students. It is most suitable for students who enjoy solving challenging math problems.

The police could issue speeding tickets in items 1a and 1c because, in both cases, the car is going 112 MPH; in 1b, the car is going 56 MPH.

a. 50 m/s = (50 m/s) × (60 s/min) × (60 min/hr)

= 180,000 m/hr

180,000 m = 180 km

180,000 m/hr = 180 km/hr × (0.62 miles/km)

= 112 MPH

b. 25 m/s = (25 m/s) × (60 s/min) × (60 min/hr)

= 90,000 m/hr

90,000 m = 90 km

90,000 m/hr = 90 km/hr × (0.62 miles/km)

= 56 MPH

c. Same as a.

EXTENSION 3

Have students create one or more new characters also riding in cars for the scenario in Part B of this activity. For each character, students should make up another set of trip strips and a motion graph to go with them.

REVISIT THE GUIDING QUESTION

How can you measure and graph the speed of a moving object?

Speed is determined by measuring the time that it takes an object to cover a certain distance. Thus, speed is a rate. Speed can be graphed with distance from a location on the *y*-axis and time on the *x*-axis. The slope of the line indicates the speed. The steeper the slope, the faster the object is moving. A flat slope means that the object is not moving. A negative slope indicates that the object is moving back toward the starting point.

ACTIVITY RESOURCES

KEY VOCABULARY

speed

BACKGROUND INFORMATION

SPEED

An object in motion takes time to change its position. Speed is the measurement of the rate of change in position and can be linear or rotational. The units for speed are a distance or an angle per unit of time, such as miles per hour or degrees per second.

Many moving objects do not travel at a constant speed. Instantaneous speed is the term given to the speed of an object at any "instant" during its journey. Average speed is the total distance the object traveled divided by the total time elapsed in traveling that distance. Objects can attain the same average speed through numerous different series of instantaneous speeds. For example, one car might travel a certain distance at a steady 40 MPH, while another makes the same trip at a speed of 30 MPH for 1 hour and 50 MPH for 1 hour. At the end of the trip, both cars will have made the trip at an average speed of 40 MPH. although their instantaneous speeds were different.

VELOCITY

Speed (s) and velocity (v) are related concepts but are not the same thing. The velocity of an object includes both its speed and its direction. Whereas speed is a *scalar* quantity, velocity is a *vector* quantity, which means that it must be described by an amount and a direction. This unit discusses the concept of speed only.

ACCELERATION

Acceleration will be addressed later in the unit. Acceleration is the time rate of change of velocity. Like velocity, it is a vector quantity that includes both an amount and a direction. In this unit, the discussion of acceleration is often limited to linear acceleration—a change in speed but not a change in direction—where the descriptions of "increasing" (+) and "decreasing" (–) are sufficient in describing the direction of acceleration. For simplicity, when nonlinear motion is mentioned, a "change in direction" is used to imply acceleration, but a specific direction is not provided.

Negative acceleration, like any acceleration, is a vector quantity that has both magnitude and direction. In linear motion, the term *negative acceleration* refers to acceleration that is a result of either a slowing down in a positive direction or a speeding up in a negative direction. For example, a car that applies brakes while moving forward (positive direction) in a straight line has negative acceleration because the acceleration is in the opposite direction as the velocity. However, a car that is speeding up while moving backward in a straight line (increasing negative values) is also said to have negative acceleration because although it is speeding up, it is doing so in the negative direction.

The term *deceleration* is used to refer to negative acceleration in the first example above—that is, when the object is moving in a straight line in the positive (+) direction and has decreasing speed from an acceleration in the opposite direction (i.e., applying the brakes). Deceleration reflects the situation presented in this activity.

DISTANCE-VS.-TIME GRAPHS

The motion of an object is defined by its change of position over a period of time. Graphs of distance vs. time are useful in describing and interpreting motion that is linear. On such a graph:

- A straight line indicates a constant speed.
- A horizontal line indicates no motion, or zero (0) speed.
- A positively sloped line (upward) indicates motion away from the reference point, or positive velocity.
- A negatively sloped line on a displacement graph indicates motion toward the reference point, or negative velocity.
- A steeper slope indicates a faster speed.
- The value of the slope is the speed defined by the graphed units of time and distance.
- A curved line of changing slope indicates linear acceleration, or a change in speed.
- The rate of curvature represents the amount of acceleration.

REFERENCES

National Highway Transportation Safety Administration. (2015). *Traffic safety facts: Speeding*. https://www.nhtsa.gov/risky-driving/speeding

Name____ Date___________

STUDENT SHEET 2.1

TRIP STRIPS

A	Car takes 4 minutes to return home (30 MPH).
B	Car travels 4 miles in 8 minutes (30 MPH).
C	Car stops for 6 minutes while picking up a friend.
D	Car travels 3 miles toward school in 6 minutes.
E	Josh, realizing he may have forgotten his homework, pulls over, and looks through his backpack for 1 minute.
F	Teasha’s car gets caught in traffic and travels 1 mile in 8 minutes (7.5 MPH).
G	Car travels 2 miles in 5 minutes.
H	Car stops for 2 minutes.

A	Car takes 4 minutes to return home (30 MPH).
B	Car travels 4 miles in 8 minutes (30 MPH).
C	Car stops for 6 minutes while picking up a friend.
D	Car travels 3 miles toward school in 6 minutes.
E	Josh, realizing he may have forgotten his homework, pulls over, and looks through his backpack for 1 minute.
F	Teasha’s car gets caught in traffic and travels 1 mile in 8 minutes (7.5 MPH).
G	Car travels 2 miles in 5 minutes.
H	Car stops for 2 minutes.

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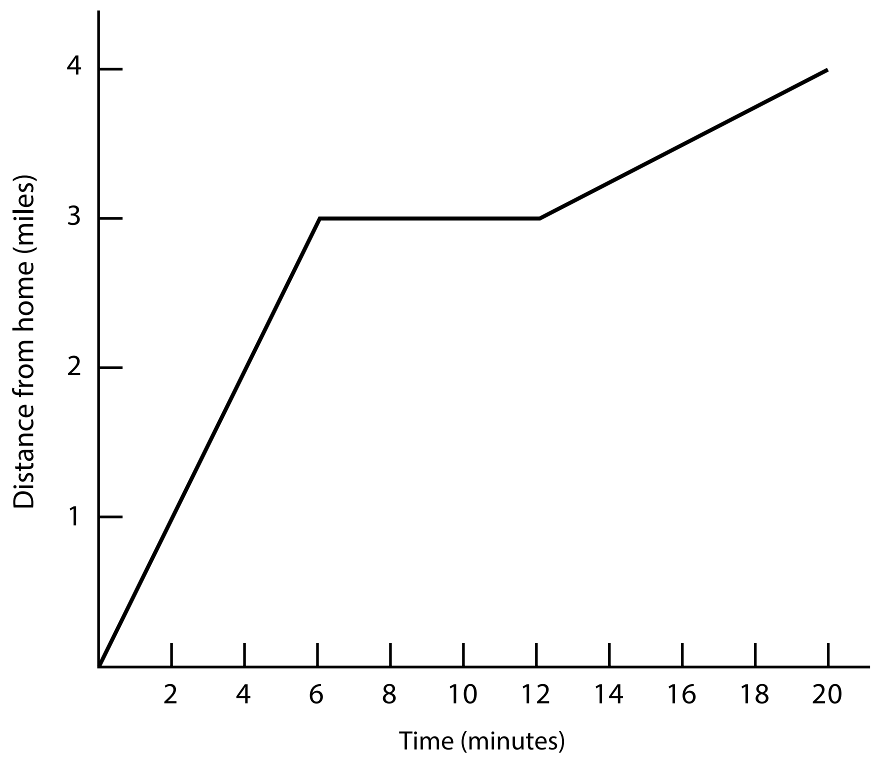
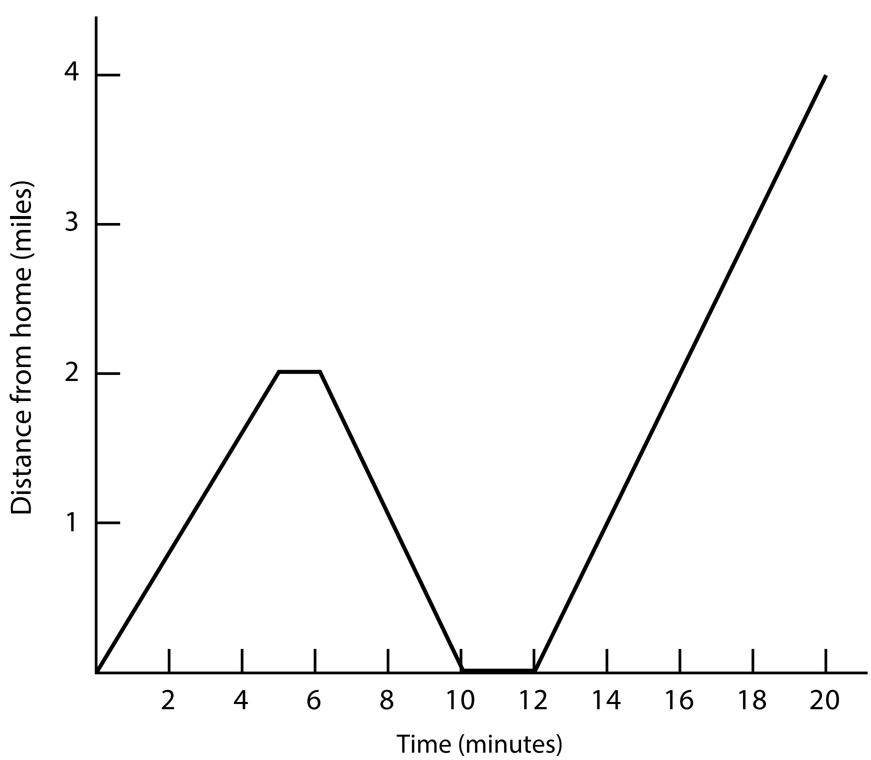
F	Teasha’s car gets caught in traffic and travels 1 mile in 8 minutes (7.5 MPH).
G	Car travels 2 miles in 5 minutes.
H	Car stops for 2 minutes.

Name____ Date__________

STUDENT SHEET 2.2

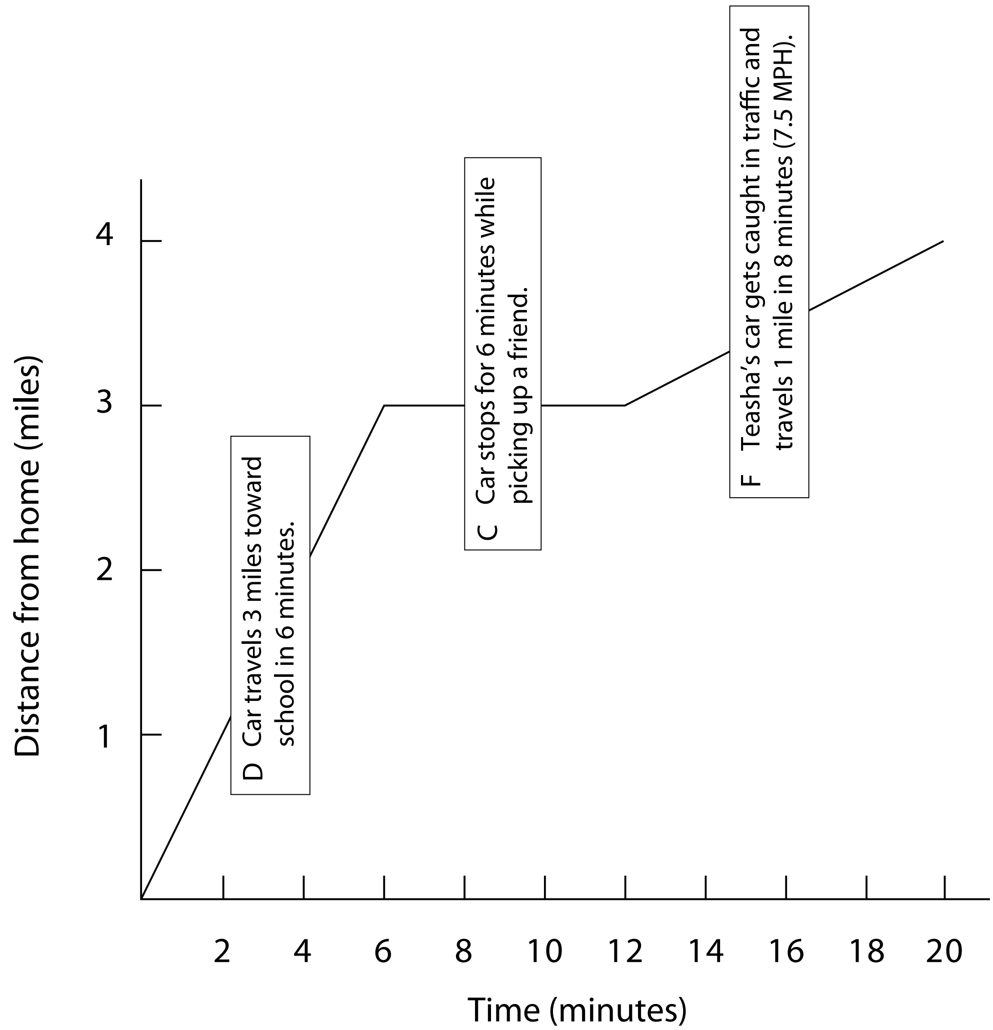
TEASHA'S AND JOSH'S TRIPS TO SCHOOL





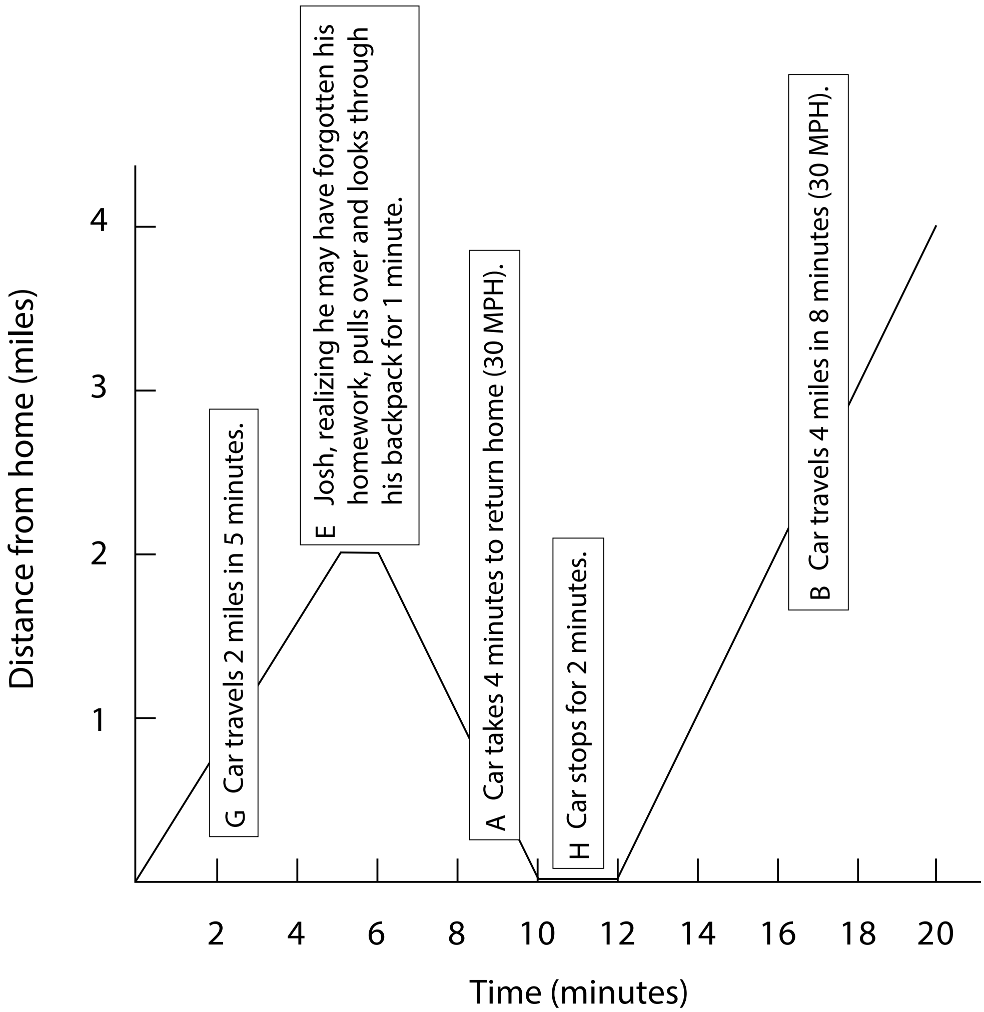
VISUAL AID 2.1a

GRAPH OF TEASHA'S TRIP TO SCHOOL



VISUAL AID 2.1b

GRAPH OF JOSH'S TRIP TO SCHOOL



VISUAL AID 2.2

GROUP INTERACTIONS CLASSROOM RUBRIC

When to use this rubric:
This classroom rubric is used when students work together as a group toward a common goal.

What to look for:
- Group members work together as a team.
- The ideas of all members are valued and considered by the whole team in working toward the common goal.

Level	Description
Level 4 Accomplished	Group members accomplish Level 3 and actively collaborate by doing the following: • Asking questions about one another's ideas • Helping one another accomplish the task • Building on one another's ideas
Level 3 Almost there	All group members participate equally, and respectfully consider one another's ideas.
Level 2 On the way	Unequal group participation OR group respectfully considers some, but not all, ideas.
Level 1 Getting started	Significantly unequal group participation OR group totally disregards some members' comments and ideas.
Level 0	Members do not work together OR single individual does entire task.
x	Student had no opportunity to work as part of a group.

3 Speed and Kinetic Energy

LABORATORY

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students further investigate speed by carrying out an investigation that relates the speed of an object to its kinetic energy. Students analyze and interpret data to determine that when their carts are released from a greater height, they go faster (because more gravitational potential energy is transformed into kinetic energy). Students confirm the positive relationship between speed and kinetic energy by examining the transfer of energy from a cart to an object in its path.

NGSS CORRELATIONS

Performance Expectations

Working toward MS-PS3-1: Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Working toward MS-PS3-2: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Disciplinary Core Ideas

MS-PS3.A Definitions of Energy: Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.

MS-PS3.C Relationship Between Energy and Forces: When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Science and Engineering Practices

Analyzing and Interpreting Data:

Construct and interpret graphical displays of data to identify linear and nonlinear relationships.

Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.

Planning and Carrying Out Investigations: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

Constructing Explanations and Designing Solutions: Construct an explanation that includes qualitative or quantitative relationships between variables that predict or describe phenomena.

Crosscutting Concepts

Scale, Proportion, and Quantity: Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Patterns: Graphs, charts, and images can be used to identify patterns in data.

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Energy and Matter: Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).

Common Core State Standards—Mathematics

6.SP.B.5: Summarize numerical data sets in relation to their context.

7.RP.A.2: Recognize and represent proportional relationships between quantities.

Common Core State Standards—ELA/Literacy

RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

INVESTIGATIVE PHENOMENA AND SENSEMAKING

Some car accidents cause more damage than others.

Students use their understanding of energy transfer to figure out that the faster a car is going, the greater its kinetic energy. They begin to make sense of how speed relates to car and driver safety.

WHAT STUDENTS DO

Students use the cart system from the “Measuring and Graphing Speed” activity to explore the qualitative relationship between the speed of the cart and its kinetic energy. Students release the carts from different heights on the ramp and measure their speed each time. Students draw on what they know about energy transformation to understand that a cart with a greater release height has more gravitational potential energy that can be transformed into kinetic energy of motion. They use their understanding of energy transfer to investigate what happens when a block is in the path of a cart. Using different release heights, students compare how far a block placed on the track moves after a cart hits it. Students discover that a faster-moving cart moves the block farther— because more kinetic energy has been transferred from the cart to the block.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Scoring Guide: ANALYZING AND INTERPRETING DATA (AID)
  - 1 Scoring Guide: ORGANIZING DATA FOR ANALYSIS (ODA) (optional)

- *For each group of four students*
  - 2 track pieces
  - 1 ramp
  - 1 cart
  - 1 block
  - masking tape
  - * 1 meter stick
  - * 1 marker
  - * calculator

If using the timer method for measuring speed

- 1 timer

If using the magnetometer method for measuring speed

- 1 smartphone holder with cart attachment
- 2 disk magnets
- 2 large rubber bands
- * 1 smartphone

- *For each student*
  - 1 Student Sheet 3.1, "Effect of Release Height on Cart Speed" (optional)
  - 1 Student Sheet 3.2, "Effect of Cart Speed on the Block" (optional)
  - 1 Scoring Guide: ANALYZING AND INTERPRETING DATA (AID) (optional)
  - 1 Scoring Guide: ORGANIZING DATA FOR ANALYSIS (ODA) (optional)

* *not included in kit*

The ANALYZING AND INTERPRETING DATA (AID) and the ORGANIZING DATA FOR ANALYSIS (ODA) Scoring Guides can be found in the Assessment tab in the back of this Teacher Edition.

Decide if students will use timers or magnetometers for measuring speed. To use magnetometers, each group will need a smartphone that has the free *Science Journal by Google* app loaded onto it.

This unit assumes that students have already completed a unit on energy and are familiar with kinetic energy and energy transfers and transformations. If students have not completed such a unit, you will need to determine how much time to devote to familiarizing your students with these concepts, enough to help them understand that in Part B, their moving carts can transfer energy to the block; measuring how far the carts move is an indicator of how much kinetic energy the moving carts have.

Teacher's Note: Students will examine the quantitative relationship between speed and kinetic energy in a later activity.

TEACHING SUMMARY

GET STARTED

1. Students review what they know about energy transformations and transfers.
   a. Write *kinetic energy* on the board, and ask students for a working definition of this term.
   b. Have a student read the introduction aloud.

DO THE ACTIVITY

2. Students collect data on the effect of ramp height on speed.
   a. Explain to students that in Part A of the activity, they will conduct an investigation to examine the effect of release height on speed.
   b. Let students know whether they will use timers or magnetometers to measure speed.
   c. Circulate throughout the room as students carry out Procedure Steps 1–6.
   d. Distribute Student Sheet 3.1, "Effect of Release Height on Cart Speed." (optional)
   e. Have groups share the average speeds they calculated for each release height, and compile them on the board.
   f. Direct students to Analysis item 1, and have them write a response in their science notebooks.
   g. Hold a brief class discussion about the patterns that students identified.

3. Students conduct Part B: exploring the relationship of speed and kinetic energy.
   a. Direct students to Procedure Step 7, and briefly discuss students' initials ideas about the relationship between speed and kinetic energy.
   b. (ODA QUICK CHECK) Point out Procedure Step 9, which requires students to copy and complete a data table.
   c. Circulate throughout the room as students conduct the investigation.

BUILD UNDERSTANDING

4. (AID ASSESSMENT) Students identify the relationship between speed and kinetic energy.
   a. Let students know that they will be assessed on Analysis item 2.
   b. Briefly discuss and summarize the main result as a class. (optional)
   c. Direct students to Analysis item 3.
   d. Direct students to Analysis item 4.

TEACHING STEPS

GET STARTED

1. Students review what they know about energy transformations and transfers.
   a. Write *kinetic energy* on the board, and ask students for a working definition of this term.

      Help students arrive at a definition that involves motion, such as motion energy, or energy of motion. Reinforce that every moving object, including the cars they ride in and the carts in their models, has kinetic energy.
   b. Have a student read the introduction aloud.

      Emphasize that in this activity, the cart gets kinetic energy from the transformation of gravitational potential energy. If students have previously completed the *Issues and Physical Science*, ENERGY unit remind them that gravitational potential energy is one type of potential energy. It is the energy stored due to an object's mass and height above the center of Earth. In the real world, our cars are able to move because of other kinds of transformations. Most typically, our cars rely on the transformation of chemical energy (from gasoline), although some modern technologies are using other kinds of transformations (e.g., electrical energy).

DO THE ACTIVITY

2. Students collect data on the effect of ramp height on speed.

   a. Explain to students that in Part A of the activity, they will conduct an investigation to examine the effect of release height on speed.

   Briefly discuss students' initial ideas about what they expect. Students are likely to say that cars released from higher will go faster.

   b. Let students know whether they will use timers or magnetometers to measure speed.

   As needed, refer to the procedures for each method in the "Measuring and Graphing Speed" activity.

   c. Circulate throughout the room as students carry out Procedure Steps 1–6.

   Probe each group for their predictions from Procedure Step 1 about the effect of release height on speed. Encourage them to use their understanding of energy transformations when making their prediction.

   Teacher's Note: Example of a thorough prediction: A cart released from Notch A has more gravitational potential energy than one released from Notch B or C because the cart released from Notch A is higher above Earth's center. Because it has more gravitational potential energy, more is transformed into kinetic energy as the cart rolls down the ramp. This will result in the cart having a higher speed.

   d. Distribute Student Sheet 3.1, "Effect of Release Height on Cart Speed." (optional)

   This Student Sheet may be helpful if students need more assistance with organizing data, or, conversely, if students are adept at organizing data but time is short.

   e. Have groups share the average speeds they calculated for each release height, and compile them on the board.

   Sample data can be found on the sample student response to Student Sheet 3.1 at the end of this activity.

   f. Direct students to Analysis item 1, and have them write a response in their science notebooks.

   g. Hold a brief class discussion about the patterns that students identified.

   If you have not already done so, introduce the crosscutting concept of *patterns*. Remind students that crosscutting concepts bridge disciplines, and can be a lens or touchstone through which students make sense of phenomena and deepen their understanding of disciplinary core ideas.

Teacher Resources

Crosscutting Concepts

Refer students to the chart in Appendix G: Crosscutting Concepts in the Student Book, and point out the symbol and definition provided. Scientists look for patterns because patterns allow them to discover relationships and develop questions about what causes these relationships.

Most students will have correctly predicted and identified the pattern that increasing the starting height increases the speed of the cart. When they are reviewing the data, remind students of the error due to timing the cart. It may be helpful when comparing speeds of the carts that traveled over different distances that the timing errors are more significant in the higher speeds because it is a larger portion of the time measured.

3. Students conduct Part B: exploring the relationship of speed and kinetic energy.

   a. Direct students to Procedure Step 7, and briefly discuss students' initials ideas about the relationship between speed and kinetic energy.

      Encourage students to reread the introduction, and make sure they understand the transformation of gravitational potential energy into kinetic energy of motion. Have students write a prediction for what would happen to a block in the path of the moving cart and how what happens might depend on the cart's release height. Have a few students share their predictions. Encourage them to use the scientific terms.

      Teacher's Note: Example of a thorough prediction: A cart released from Notch A has more kinetic energy because it is going faster. It will move the other object farther down the track because it can transfer more kinetic energy.

   b. (ODA QUICK CHECK) Point out Procedure Step 9, which requires students to copy and complete a data table.

      Note that while the structure of the data table is provided, students are required to identify the dependent and independent variables. If your students are not familiar with independent and dependent variables, it may be helpful to give them an everyday example question, such as, "How does the weather outside—the independent variable—affect the kind of clothing you wear—the dependent variable?" Have a brief discussion about these questions to clarify the meaning of the two terms for students.

      Students also need to fill in the units of measure. You might use this data table as a Quick Check on how well students can organize data. Consider projecting the ORGANIZING DATA FOR ANALYSIS (ODA) Scoring Guide. Explain that students will not be assessed on this data table but that this skill is essential for the rest of the unit. Point out how the ODA Scoring Guide has the same levels as previous Scoring Guides but different descriptions for each level. Review the levels as needed.

Teacher Resources
SEPUP Scoring Guides

For students who need more scaffolding, consider using Student Sheet 3.2, "Effect of Cart Speed on the Block." This sheet has the variables and units provided.

c. Circulate throughout the room as students conduct the investigation.

When student groups have finished all five trials for all three release heights (which correspond to speed), they should calculate the average for each height.

BUILD UNDERSTANDING

4. (AID ASSESSMENT) Students identify the relationship between speed and kinetic energy.

a. Let students know that they will be assessed on Analysis item 2.

If you have not already done so, display or distribute the AID Scoring Guide, and review the levels as needed. A sample Level 4 response can be found in the Sample Responses to Analysis.

b. Briefly discuss and summarize the main result as a class. (optional)

Teacher's Note: Students do not identify the relationship quantitatively in this activity; they will do so in a subsequent activity.

Students should be able to point out that the data show a clear relationship between speed and block movement because as the cart started higher on the ramp, the block moved farther. Assuming that the block distance reflects the amount of kinetic energy that was transformed, and that a higher release height results in faster speed, students can conclude that there is a relationship between the increased speed of the cart and kinetic energy. Sample data can be found on the sample student response to Student Sheet 3.2 at the end of this activity.

c. Direct students to Analysis item 3.

Analysis item 3 provides an additional opportunity for students to discuss the relationship between speed and kinetic energy.

d. Direct students to Analysis item 4.

Point out that this item includes the phrase "revisit the issue." Throughout the unit, students will respond to Analysis items that ask them to relate what they have learned about scientific concepts to the issue of car and driver safety. Students may find it helpful to return to their answers to these items during the "Designing a Car and Driver Safety System" activity at the end of the unit. Analysis item 4 asks students to consider how the results of this investigation relate to car and driver safety.

STRATEGIES FOR TEACHING DIVERSE LEARNERS

Below are suggestions for differentiating instruction and assessment in this activity for diverse learners in your classroom:

- Students with learning disabilities: Conduct the first trial as a whole class before instructing groups to conduct their own trials.
- Academically gifted students: Have students conduct additional trials and graph their results.

SAMPLE RESPONSES TO ANALYSIS

1. According to your data from Part A, what is the effect of release height on speed?

   Students' responses will likely vary. A sample response is shown here:

   The speed of the cart went from 123 cm/s to 82 m/s to 56 m/s as the height was decreased from Notch A to B to C. So, the greater the release height, the greater the speed.

2. (AID ASSESSMENT) According to your data from Part B, what is the effect of speed on the movement of the block? Describe and explain the pattern you observed.

   SAMPLE LEVEL 4 RESPONSE

   The higher the notch that the cart was released from, the farther the block moved. The block moved farthest when released from Notch A. Because we know from Part A that a higher notch corresponds to a greater speed, this means that the faster the cart was moving, the farther the block moved.

3. Your friend says that an object moving at a faster speed has more kinetic energy. Do you agree with your friend? Use evidence from this activity to describe why or why not.

   I agree with my friend. The faster-moving cart has more kinetic energy because there was more gravitational potential energy transformed into kinetic energy of motion. We also saw that the faster-moving cart pushed the block farther along the track. This was because the faster-moving cart transferred more kinetic energy to the block when the cart hit it.

4. **Revisit the issue:** How do you think speed affects car and driver safety?

   The faster the car is moving, the more kinetic energy it has. This may mean that when a car gets into an accident, there is more energy transferred to the other cars or objects it hits. This might result in more damage or injuries.

REVISIT THE GUIDING QUESTION

What is the relationship between an object's speed and its kinetic energy?

The faster an object is moving, the more kinetic energy it has. We confirmed this by noting that a faster-moving cart pushes a block in its path farther than a slower-moving cart does.

ACTIVITY RESOURCES

KEY VOCABULARY

kinetic energy

speed

BACKGROUND INFORMATION

POTENTIAL AND KINETIC ENERGY

Potential energy is often referred to as stored energy, and it can come in many forms. Some of these are chemical (e.g., the energy in food and gasoline), gravitational (e.g., a tree about to fall), nuclear (i.e., the energy in the nucleus of an atom that is released by fusion or fission), and mechanical (e.g., the energy that is stored in a spring or rubber band).

Gravitational potential energy is a particular type of potential energy that is a result of an object's position above Earth's center. It depends on mass (m), the acceleration due to gravity (g), and height (h). Specifically,

gravitational potential energy = mgh

The higher and/or more massive an object is, the greater its gravitational potential energy. Imagine dropping a 1-kg mass from 1 cm above your toe. It will hurt, but not too much. But if you drop it from 1,000 cm above, it would impart 1,000 times more energy and could easily break a bone. Gravitational potential energy also depends on the mass of the object. When dropped from the same heights, a 10-kg mass will impart 10 times more energy than a 1-kg mass.

Kinetic energy (KE) is the energy an object possesses because of its motion. It is dependent on the mass (m) and velocity (v) of an object. Specifically,

KE = $\frac{1}{2}mv^2$

The faster an object is moving and/or the more massive it is, the greater its kinetic energy. Thus, if the mass doubles, the kinetic energy doubles. However, when the speed doubles, the kinetic energy quadruples.

ENERGY TRANSFER AND TRANSFORMATION

Understanding energy transfer and transformation is essential in the study of energy because these interactions present our only visible evidence of energy. Energy is an abstract concept and can only be observed during transfer or transformation. In this unit, the term *energy transformation* refers to the change of energy from one type, such as potential, to another, such as kinetic. Energy transfer describes the transfer of energy from one object to another, such as the transfer of the kinetic energy of a cart to a block.

ENERGY AND FORCE

The terms *energy* and *force* are both related to motion and are often confused and misused. Energy is the ability of an object to do work (work, as used by physicists, relates to the force and distance that an object is moved). Energy can be kinetic (the energy of motion) or potential (stored energy).

A force is a push or pull that can cause a change in motion. Unlike energy, forces cause objects to move but are not contained within the object. Forces exist only when two or more objects interact and are applied from one object to another.

This unit begins with a discussion of the kinetic energy of a moving object and later addresses the idea that forces are what cause an object to change speed (and/or direction).

Name____ Date___________

STUDENT SHEET 3.1

EFFECT OF RELEASE HEIGHT ON CART SPEED

Release position	Distance (cm)	Time (s)	Speed (cm/s)	Average speed (cm/s)
A				
A				
A				
B				
B				
B				
C				
C				
C				

Name____ Date____________

STUDENT SHEET 3.2

EFFECT OF CART SPEED ON THE BLOCK

Speed (release height)	Distance block moves (cm)					Average distance (cm)
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	
Fast (Notch A)						
Medium (Notch B)						
Slow (Notch C)						

Name *Sample student response* Date

STUDENT SHEET 3.1

EFFECT OF RELEASE HEIGHT ON CART SPEED

Release position	Distance (cm)	Time (s)	Speed (cm/s)	Average speed (cm/s)
A	*50*	*0.43*	*116*	
A	*50*	*0.40*	*125*	*123*
A	*50*	*0.39*	*128*	
B	*50*	*0.52*	*96*	
B	*50*	*0.57*	*88*	*88*
B	*50*	*0.62*	*81*	
C	*50*	*0.91*	*55*	
C	*50*	*0.84*	*59*	*56*
C	*50*	*0.94*	*53*	

Name *Sample student response* Date

STUDENT SHEET 3.2

EFFECT OF CART SPEED ON THE BLOCK

Speed (release height)	Distance block moves (cm)					Average distance (cm)
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	
Fast (Notch A)	*12.5*	*15.5*	*15.0*	*14.0*	*15.5*	*14.5*
Medium (Notch B)	*9.0*	*9.0*	*8.0*	*9.0*	*9.0*	*9.0*
Slow (Notch C)	*5.5*	*5.5*	*5.5*	*5.5*	*6.0*	*5.5*