A Model for Constant Velocity

A Carolina Essentials™ Activity

Overview

Constant velocity is the foundation of understanding motion in physical science. Using a constant velocity car, students quickly collect data for distance and time, then use the data to develop a model showing that distance is proportional to time. Through graphical analysis, students also develop the formula for speed by taking the slope of the line on their graph. This approach to introducing constant velocity is visual, and it requires data analysis and interpretation as well as model building. Students are practicing science, not just memorizing a formula.

Physical
Grades: 9–12

Phenomenon

Briefly share the fable "The Tortoise and the Hare" with students. Ask them to sketch the motion of both animals in the fable and share the sketch with their lab partners.

Essential Question

How is motion modeled both graphically and mathematically?

Activity Objectives

1. Collect and analyze data for an object moving at constant velocity.
2. Develop a predictive mathematical model that describes the motion of an object moving with a constant velocity.

Next Generation Science Standards* (NGSS)

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution.	**PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Safety Procedures and Precautions

Examine all batteries prior to the activity. Properly dispose of or recycle any batteries that show signs of corrosion or leakage.

TIME REQUIREMENTS

PREP	ACTIVITY
15 min	30–45 min

Teacher Prep: 15 min
Student Activity: 30–45 min

SAFETY REQUIREMENTS

No PPE is required for the activity.

MATERIALS (PER GROUP)

- Constant velocity vehicle
- Wood dowel, 7/8 × 1-7/8 in
- Square of aluminum foil, 10 × 10 cm
- Tape measure or meter stick
- 3 stopwatches or smartphones
- Graph paper
- Calculator
- 2 batteries, size C

OPTIONAL:

- Digital video recorder
- Laptop, computer, or digital device
- Motion sensor

HELPFUL LINKS

Improving Students' Math Skills for Science Class

Physical Science Math Review: Techniques, Formulae, and Constants

Derivation of the Kinematics Equation

REFERENCE KITS

Constant Velocity Vehicle

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Teacher Preparation and Disposal

Identify a location where students may perform the experiment. (The area should be clear, level, and free from foot traffic.) Precut the dowels and the aluminum foil squares. Place students in groups of 5 or 6. Test the constant velocity vehicle and change batteries if necessary. Make sure to securely replace the battery cover.

Dispose of the aluminum foil in the classroom trash or recycle. Do not discard the dowels as they can be reused.

Student Procedure

Procedure A

1. Prepare a straight, level track/path at least 3 meters long, where you can operate the constant velocity vehicle.
2. Prepare the vehicle by installing the batteries and closing the battery compartment.
3. Test the vehicle. Place it on the track you prepared, and switch on the power. Allow the car to run the length of the track. If the car veers to the left or the right (more than twice the width of the car, or over 3 meters), modify the track to correct the path.
4. Once your test track is prepared, set the car on the floor at least a car length behind the start point.
5. One group member needs to be behind the start point to activate the car. A second member stands at the start point to signal the timers to start. Three students stand at designated meter points to take times. One student should be located behind the finish line to recover the car.
6. Record the position of each student with a timer from the start position. Mark this position on the track with a piece of tape.
7. Start the car by switching on the power and release the car to travel the track.

Teacher Preparation and Tips

The car may veer. It may be necessary to set up a guide to keep the car traveling in a straight path. This can be done by arranging a row of books, taping meter sticks to the floor, or running the car along a wall.

This will slow the car due to friction. If students run the experiment with the same conditions during each trial, the small amount of friction will not adversely affect the results.

Make sure the compartment is secure. A loose compartment door can detach during the experiment and catch on a book, meter stick, or other object, affecting results and possibly damage the vehicle.

Look at the car prior to the experiment, and make sure you have any tools necessary to open, close, and secure the compartment. A small screwdriver may be required to open and close the compartment.

See the notes for step 1, the preparation of the track. Allow students to develop their own methods for correcting the motion of the car, if necessary. Prompt students by suggesting the methods discussed in the notes for step 1.

Students should ensure that the car will travel a straight path over the length of 3 meters before proceeding.

Setting the car behind the start point allows the car to reach full speed before crossing the start point.

It also allows the students operating timers to prepare so that they may start their devices when the car crosses the start point.

Positioning the student who signals the timers to begin at the start point puts this student in a position where he/she can look straight down as the car crosses the start point, eliminating parallax error.

Before starting the experiment, students should test their timers to make sure they know how to start, stop, and reset them.

You may also want to ask students to start and stop their devices as quickly as possible. This gives students an idea about the minimum amount of error introduced due to reaction time.

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Student Procedure

8. When the car crosses the start point, the student at that position signals the timers to start. On the starter's signal, all timers start their stopwatches/timers.

9. As the vehicle crosses the position on the track next to each timer, that student will stop his/her stopwatch.

10. Repeat the experiment 2 more times. Record the time for each trial at each position.

11. Average the 3 times for each position.

Procedure B

12. Remove 1 battery from the constant velocity vehicle. Wrap the wooden dowel completely with aluminum foil to make a battery jumper. Place it in the battery compartment so the jumper is in the negative end of the battery compartment, near the spring. Switch on the car to make sure it works.

13. Repeat procedure A with the modified vehicle.

Teacher Preparation and Tips

Students observing the experiment should record the data in their notebooks.

You may choose to assign additional students to record data on a whiteboard or laptop, or to use a probe or video recorder.

Recording the time interval measured from t = 0 for several positions along the track provides several data points.

Recording multiple measurements for trials is a good practice that helps reduce error and identify outliers.

If you have more timers or stopwatches, multiple students may record the data at each position, eliminating the need for multiple trials. Students should be located where they can directly observe the car as it crosses the designated position to remove parallax error.

Students must make certain the dowel is completely covered. There must be a complete, secure connection between the aluminum foil and the battery connectors.

Data and Observation

Construct data tables for procedures A and B. Be sure to record your units of measure.

Procedure A: Sample Data

Distance vs. Time Data for Constant Velocity Vehicle (2 batteries)			
Distance (m)	**Time (s)**		**Average Time**
1	**Trial 1**	*3.0*	*3.0 s*
	Trial 2	*2.9*	
	Trial 3	*3.1*	
2	**Trial 1**	*6.2*	*6.0 s*
	Trial 2	*5.8*	
	Trial 3	*6.0*	
3	**Trial 1**	*9.4*	*9.0 s*
	Trial 2	*8.9*	
	Trial 3	*8.7*	

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Data and Observation

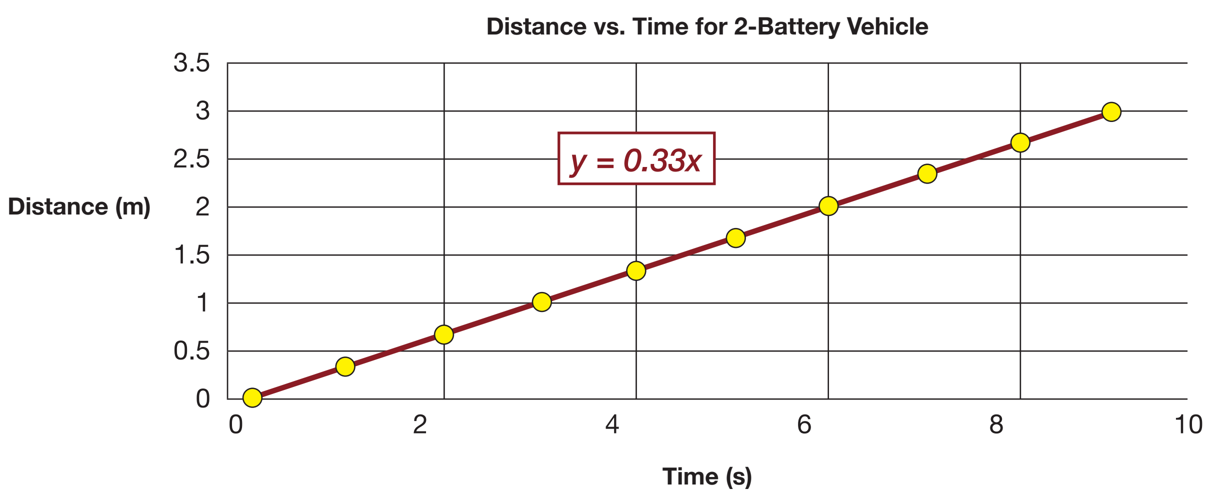
Construct data tables for procedures A and B. Be sure to record your units of measure.

Procedure B: Sample Data

Distance vs. Time Data for Constant Velocity Vehicle (2 batteries)			
Distance (m)	**Time (s)**		**Average Time**
1	**Trial 1**	*6.7*	*6.0 s*
	Trial 2	*5.3*	
	Trial 3	*6.0*	
2	**Trial 1**	*13.2*	*12.0 s*
	Trial 2	*12.8*	
	Trial 3	*12.0*	
3	**Trial 1**	*18.4*	*18.0 s*
	Trial 2	*17.9*	
	Trial 3	*17.7*	

Analysis and Discussion

1. Construct a graph for both sets of data. Color code the data. Consider these questions as you construct the graphs:
   1. What variable should be recorded on the y-axis? *Distance*
   2. What variable should be recorded on the x-axis? *Time*
   3. What units of measure should you assign to each variable? *Distance in meters and time in seconds*
   4. What should you label each axis? *Distance (m) and Time (s)*
   5. What title should you assign your graph? *Distance vs. Time for a Constant Velocity Car with 2 Batteries and Distance vs. Time for a Constant Velocity Car with 1 Battery*
   6. How will you scale your graph? *Time in seconds or half seconds, distance in half meters*



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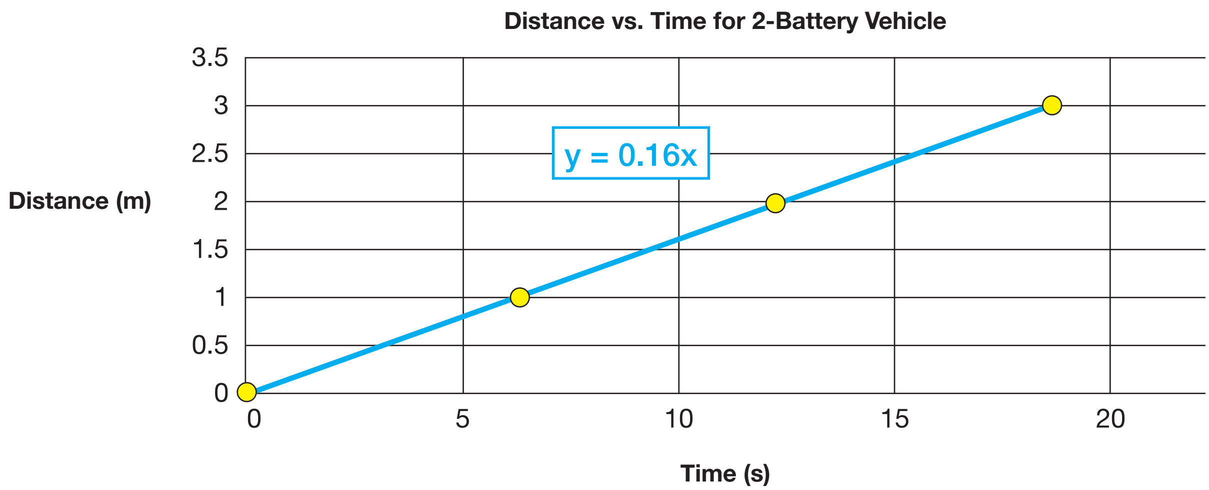

2. What does the shape of the line indicate about the motion of the vehicle?

   The graph of the data has the shape of a line. This indicates that the variables, distance, and time are directly proportional: d α t.

3. What is the effect of removing a battery on the velocity of the vehicle? What graphical evidence supports your claim?

   The speed of the vehicle is less than the original vehicle, and the slope of the line is smaller.

4. How can you determine the speed of the car from the graph of the data?

   The speed of the car is represented by the slope of the line. This can be calculated using the point slope formula:

$$m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1\ (m)}{x_2 - x_1\ (s)}$$

   Substituting two values from the graph:

$$m = \frac{3-1}{9-3} = 0.33\,(m/s) \qquad m = \frac{3-1}{18-6} = 0.16\,(m/s)$$

5. Scientific models must be predictive. Does the graph of the car's motion meet this definition? How could you use the graph to predict the position of the car at a future time?

   Yes, the graph is predictive. To find the position of the car at some time t, extend the graph so that the line crosses that value for time and read the value for distance from the y-axis.

6. Use what you have learned to interpret the graph you drew of the race between the tortoise and the hare. Identify the type of motion, constant velocity or rest, and relative speed (slope of the line).

   Student answers will vary. Any horizontal line segment should be interpreted as rest. The steeper the slope, the faster the speed. If you have already introduced velocity, also look for explanations of change in direction.

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TEACHER NOTES

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