



Understanding Graphs of Motion

Activity Overview

Graphical data representing the relationships between distance, time, and velocity are commonly explored in science classrooms. At the same time, these concepts can be abstract and difficult for students to visualize and understand. Engaging students in an activity in which they are asked to conduct an experiment, collect data, and interpret results in order to answer a question can encourage them to develop meaningful understandings of science concepts. In the process, students practice skills of inquiry, reasoning and argumentation that are also central to understanding the nature of science.



In this activity students will explore the question: Can humans walk at a constant velocity? On the surface, an answer to this question seems obvious, and based on their own experience students are usually quick to predict that it is quite easy to walk at a constant velocity. However, when using the motion detector, more detailed measurements can be made that reveal great variability in velocity during walking. It is actually very challenging to walk at a constant velocity for any length of time.

Advantages of Technology

In this activity, students collect real-time data using ultrasonic motion detector probes and graphing calculators. These technology tools allow for the exploration of meaningful questions that would otherwise be impossible in a typical science classroom. In addition, these tools allow students to focus their attention on the interpretation of data they collect — not its mundane and time consuming collection. The real-time graphical representations of students' motion on the graphing calculator allow them to build kinesthetic and cognitive connections between their actual physical motion and its representation on a distance v. time graph.

Educational Standards

This activity can be used to address the following Virginia SOL's in middle school and high school settings.

Grade 8

PS.1 The student will plan and conduct investigations.

PS.10 The students will investigate and understand scientific principals and technological applications of work, force and motion. (Key concepts include speed / velocity)

Physics

PH.1 The student will understand how to plan and conduct investigations.

PH.2 The student will investigate and understand how to analyze and interpret data. (Key concepts include understanding that relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data.)

PH.5 The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. (Key concepts include linear motion.)

Materials

Technology:

- Ultrasonic Motion Detector or Sonic Ranger
- Vernier Lab Pro
- TI-83 Calculator or Computer

Other Supplies:

Large piece of cardboard (Flat surface provides for more accurate readings by motion detector)

Procedure

This activity assumes that students have had experience and are familiar with using the TI-83 graphing calculator and Vernier's DataMate program for collecting and manipulating data.

You can begin the activity by pacing slowly back and forth in the classroom. While pacing, ask students: "Is it possible for humans to walk at a constant velocity?" Have students make individual predictions and provide reasons to support their ideas. Encourage students to share some of their predictions and reasons in small groups and the whole class.

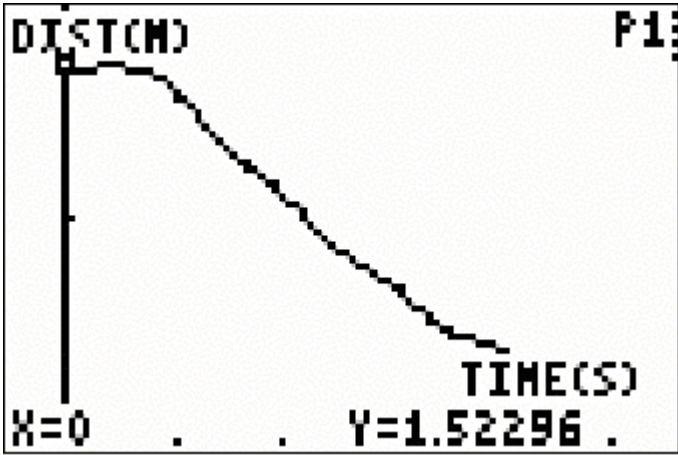
Understanding the Direction of Motion and Negative/Positive Values for Velocity

Prior to students' planning and conducting their experiment, you should guide them through a few trial runs. Students should be encouraged to share roles throughout the activity so each gets the opportunity to collect data, as well as being the moving target. With one student walking and holding the cardboard target, have them collect data for the following action:

Walking slowly away from the motion detector.

Walking slowly toward the motion detector.

A positively sloping line indicates motion away from the detector, while a negatively sloping line indicates motion toward the detector. Negative and positive values for velocity indicate direction. A graph of the motion of a student walking toward the motion detector (negative sloping line) might appear like this one the calculator:



Engage students in a brief discussion of the following questions:

- *What variables are represented on the X and Y axes?*

- *What does the negative and positive value of the slope of the line indicate about the motion?*
- *Does your graph show constant velocity? What would a graph showing constant velocity look like?*

Understanding the Connection Between Slope and Velocity

In this phase of the activity, students can use the distance and time data they collected to develop an understanding of the relationship between the slope of a line and the average velocity. The slope of a line for a distance vs. time graph represents the velocity for the object in motion. Slope can be determined using the following formula:

$$m = \frac{y_1 - y_2}{x_1 - x_2}$$

For a distance v. time graph, the change in y values divided by the change in x values determines the average velocity for the object between any two points. Direct students to select the first and last points on their graph, and use the x and y values for determining the slope of the line. By finding the change in distance ($y_1 - y_2$) and dividing it by the change in time ($x_1 - x_2$) students can determine average velocity between these two points.

Predicting Acceleration and Deceleration

The graph forms produced from the walking trials are likely to show changes in velocity over time. In other words, students were accelerating and decelerating during their walking motion. Sometimes students see little difference between velocity and acceleration. This situation presents an ideal opportunity to introduce the concept of acceleration as a change in velocity over time. Encouraging students to predict what a graph of acceleration versus time would look like for their data can help them to begin forming a more meaningful understanding of the concepts of velocity and acceleration.

Plan and Conduct the Investigation

Encourage students to work collaboratively in small groups to plan and conduct an investigation that seeks to answer the question, "Can humans walk at a constant velocity?" Ask students to do the following when completing this task:

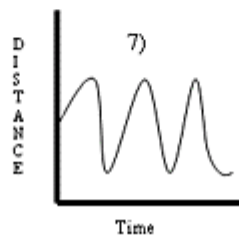
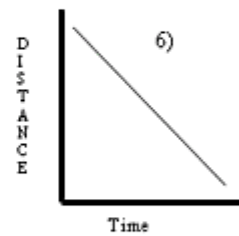
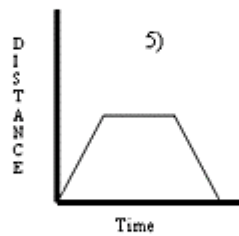
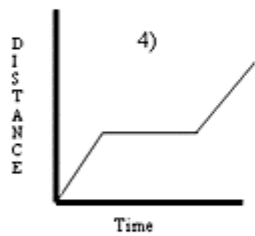
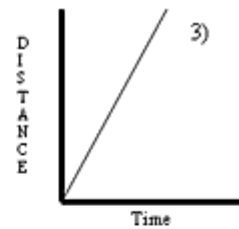
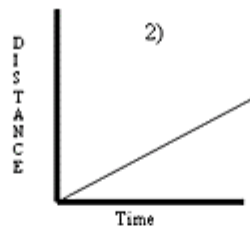
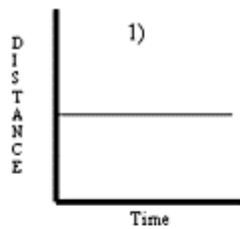
- Consider the appropriate number of trials to conduct. Justify your decision.
- Describe in detail the procedure your group followed to complete the investigation. Provide written product.
- Present the data collected in the form of tables and graphs.

- Discuss the results of your investigation with your group.
- Based on the data your group collected, come to a consensus about a possible solution to the question. Provide evidence to support your reasoning.
- Offer new questions your group has as a result of completing this investigation.

Provide each group of students the opportunity to present, discuss, and defend the results of their investigation with the class. The presentations provide excellent opportunities for student learning, as well as teacher assessment of student conceptual understandings.

Assessment Strategies

This activity could be assessed in many different ways. Students could be asked to describe or physically reproduce the motion of the objects whose distance vs. time graph are given, as in the examples below. Students could also be encouraged to generate graph forms of their own and challenge other groups or the teacher to reproduce the corresponding motion.



Contact:

Randy L. Bell
Asst Professor of Science Education
Curry School of Education
University of Virginia
Charlottesville, VA 22904
email: randybell@virginia.edu