Teacher Guide: Distance-Time and Velocity-Time Graphs

Learning Objectives

Students will…

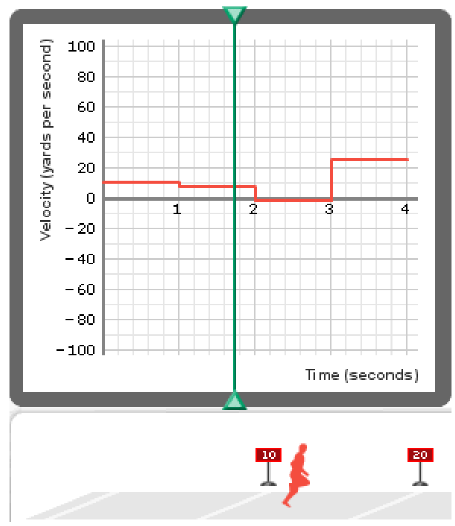
- Observe the relationships among a running person, a graph of position vs. time, and a graph of velocity vs. time.
- Determine the velocity of an object based on a graph of its motion.
- Create a velocity-time graph from a given position-time graph.
- Explain the difference between speed and velocity.
- Explain the difference between distance traveled and displacement.
- Calculate average speed and average velocity, and understand how they differ.

Vocabulary

displacement, distance traveled, slope, speed, velocity

Lesson Overview

The *Distance-Time and Velocity-Time Graphs* Gizmo™ and Student Exploration guide were designed as a follow-up to the *Distance-Time Graphs* Gizmo. The *Distance-Time and Velocity-Time Graphs* Gizmo adds a velocity-time graph and a total distance traveled graph.



The Student Exploration contains three activities:

- Activity A – Students compare a position-time graph to a velocity-time graph.
- Activity B – Students create a velocity-time graph based on a position-time graph.
- Activity C – Students distinguish displacement (net change in position) from distance traveled.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Distance-Time Graphs** (45 – 60 minutes)
Have your students do the Student Exploration for the *Distance-Time Graphs* Gizmo. (This isn't required, but it is important that students understand the concepts presented there – graphing position over time, and what that can tell you about motion.) While doing these activities, students will learn how to understand and interpret a position-time graph. Students also will solve word problems by graphing the motion of two runners.

2. **Prior to using the Gizmo** (10 – 15 minutes)
Before students are at the computers, pass out the Student Explorations and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (10 – 15 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:
   - How does a velocity-time graph show each of the following situations?
     - A runner moving quickly from left to right.
     - A runner moving slowly from right to left.
     - A runner at rest.
   - How does a position-time graph show the three types of runners listed above?
   - Can a runner's starting position be inferred by looking at a velocity-time graph? Why or why not? [The answer is no. A velocity-time graph shows starting velocity, but it says nothing about starting position.]
   - Could you make an accurate velocity-time graph based on a distance traveled graph? Explain why or why not. [No, you can't. With a distance traveled graph, you can't tell which direction a runner is moving.]

5. **Follow-up activity: Graph practice** (30 – 45 minutes)
Have students practice making velocity-time graphs based on position-time graphs. Student volunteers can create position-time graphs using the Gizmo, and project each graph to the front of the classroom. Have the remaining students sketch velocity-time graphs that correspond to the position-time graph they see. Then reveal the velocity-time graph in the Gizmo and have students evaluate how they did.

   You can also collect data from actual running students to make graphs. Mark a straight course on an athletic field. Place student "timers" every 5 or 10 yards along the course. On "Go," a runner starts and all the timers start their stopwatches. As the runner passes each timer, the stopwatch is stopped and the time is recorded. Once data has been recorded, enter the position and time data into a spreadsheet. Create a position-time graph from the data. Then use this to create a velocity-time graph. (The slope of each segment of the position-time graph is the velocity.)

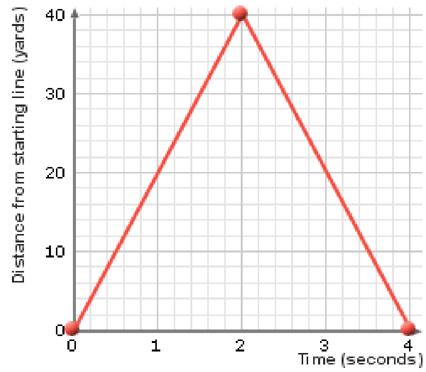
Mathematical Background
Speed and velocity are related but they are not the same. Here's an illustration: If you say that you are driving 30 miles per hour, you have stated the *speed* of your car. If you say that you are driving north at 30 miles per hour, then you have given speed and direction – that is *velocity*.

Speed gives a magnitude (an amount or number) but no direction. (A car's speedometer tells you the car's speed at any moment.) Values such as speed that specify a magnitude and no direction are called *scalar* quantities. Scalar quantities can be zero but never negative.

Velocity describes both magnitude (speed) and direction. Quantities that give both magnitude and direction are called *vector* quantities. Vectors are often represented as arrows. The length of the arrow shows the magnitude, and the direction of the arrow shows the direction of motion.

Velocity can be positive or negative. If the motion is horizontal, motion to the right is positive and motion to the left is negative. For vertical motion, up is positive while down is negative.

Consider a (very speedy) runner who runs 40 yards from left to right in 2 seconds, then returns to his starting position, again in 2 seconds. The runner's motion is represented by the position-time graph at right.



In the first two seconds, the runner travels 40 yards. In the next two seconds, he goes 40 yards the other way. In the four-second interval overall, the runner has a total *distance traveled* of 80 yards. However, the runner's *displacement* is zero because he finished in the same spot as he started.

To calculate the runner's *average speed* during this run, divide the total distance by the total time: 80 y ÷ 4 s = 20 y/s.

However, the velocity changes halfway through the run because the runner's direction changes. His velocity in the first 2 seconds is 40 y ÷ 2 s = 20 y/s. His velocity in the next 2 seconds is negative: (-40 y) ÷ 2 s = -20 y/s. Therefore, the *average velocity* is 0 y/s.

The difference between average speed and average velocity is that speed measures the distance traveled per unit time. Velocity measures an object's *displacement* per unit time. (Displacement is the difference between the starting and ending position – it ignores any amount of "back-and-forth" that may have happened in between.)

average speed = distance traveled ÷ time   average velocity = displacement ÷ time

Therefore, the average speed and average velocity of an object can be very different. (At any given moment though, a runner's or object's speed is equal to the magnitude of the velocity. This is called *instantaneous* speed; this is what a car's speedometer displays.)

Speed and distance traveled are scalars and can never be negative. Velocity and displacement contain information about direction, so they are vectors and can be negative. In addition, other quantities in physics that depend on displacement are also vectors. These include velocity, momentum, acceleration, and force.

Selected Web Resources
Speed and velocity: http://www.glenbrook.k12.il.us/GBSSCI/PHYS/CLASS/1DKin/U1L1d.html, http://hypertextbook.com/physics/mechanics/velocity/, http://www.regentsprep.org/Regents/physics/phys01/velocity/default.htm
Velocity-time graphs: http://www.glenbrook.k12.il.us/gbssci/Phys/Class/1DKin/U1L4b.html
Speed and velocity misconceptions: http://memo.cgu.edu.tw/yun-ju/cguweb/SciEdu/Publication/20080221CASE/YJChiuCASE2008%20FullPaper.pdf

Related Gizmos:
Distance-Time Graphs: http://www.explorelearning.com/gizmo/id?260
Elevator Operator: http://www.explorelearning.com/gizmo/id?1017
Fan Cart Physics: http://www.explorelearning.com/gizmo/id?403