13. Position: Match Graph

Objectives

This activity introduces students to the concept of representing motion as a change of position in a graphical form. Students:

- Understand the difference between distance and position
- Experience motion as a change of position
- Interpret a position versus time graph

Procedural Overview

Students will gain experience conducting the following procedures:

- Measuring the position of an object using a motion sensor
- Tracking the change of position of an object using a graphical representation
- Interpreting a graphical representation of position versus time

Time Requirement

♦ Preparation time	5 minutes
♦ Pre-lab discussion and activity	10 minutes
♦ Lab activity	20 minutes

Materials and Equipment

For each student or group:

- Data collection system
- Object to hold (textbook, basket ball) (optional)
- Motion sensor
- Rod stand for motion sensor (optional)

Concepts Students Should Already Know

Students should be familiar with the following concept:

- *x-y* graphing

Related Labs in This Guide

Labs conceptually related to this one include:

- Speed and Velocity
- Acceleration

Using Your Data Collection System

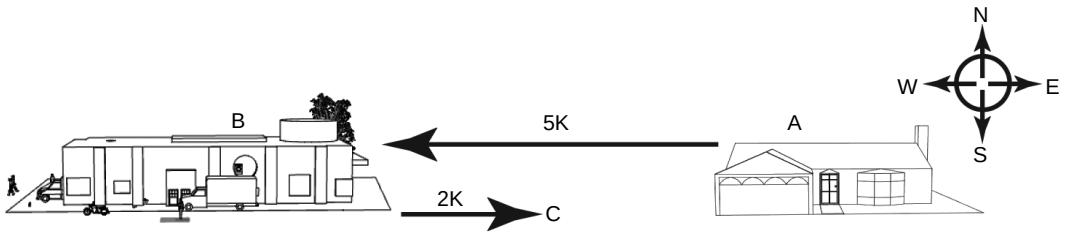
Students use the following technical procedures in this activity. The instructions for them (identified by the number following the symbol: "") are on the storage device that accompanies this manual. Choose the file that corresponds to your PASCO data collection system. Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system (1.2)
- Connecting a sensor to the data collection system (2.1)
- Starting and stopping data recording (6.2)
- Displaying data in a graph (7.1.1)
- Measuring the distance between two points in a graph (9.2)
- Adding a note to a graph (7.1.5)
- Saving your experiment (11.1)

Background

The terms distance, position, and distance traveled are often used interchangeably in everyday language. We also describe a fourth term in science, displacement. Displacement is the vector quantity describing a change in position. This can cause confusion when students begin their study of motion because the terms often have very different meanings when they are used in science. Motion is a change in position relative to a frame of reference. Distance refers to the amount of space between points. In other words, it is a length. Position refers to the location (distance and direction) of an object relative to a specific frame of reference.

To reiterate, position includes both direction and distance from a frame of reference. For example, if you tell someone the distance to your house from the mall, you might say, "five kilometers" (5 km). However, if you tell someone the position of your house (point A), you might say, "5 kilometers east of the mall (point B)."



In this description, the distance is 5 km, the direction is east, and the frame of reference is the mall. The distance traveled is the total distance required to get from one position to another.

Assuming you travel on a straight road to the mall, your distance traveled is 5 km and your position is 5 km west of your home. Now, imagine that you turn around and travel from this position toward your house, going a distance of 2 km (point C). Your total distance traveled is then 7 km (5 km + 2 km), but your position is 3 km (5 km – 2 km) west of your house. In this example, the distance is 3 km, the direction is west, and the frame of reference is your house.

Therefore, in this example, your displacement is the vector sum of 5 km away from your house and 2 km toward your house, resulting in a displacement of 3 km west of your house. Frame of reference refers to the location of the observer while measurements are made of position, motion, or both.

For this activity, the motion sensor serves as the point of reference. All motion is relative to the face of the motion sensor, with the motion away from the sensor being the positive direction.

Pre-Lab Discussion and Activity

Depending on your students' math proficiency, it may be necessary to review basic *X-Y* graphing. Lay out a tape measure or other distance measuring device next to the path you will walk to represent the *y*-axis. The motion sensor uses echolocation to determine the distance to an object. Use a digits display (projected if possible) to show the distance to near-by objects (the floor, the ceiling, or a nearby student). Next use your hand to show how distance changes when an object moves toward and away from the sensor. Also, move your hand side to side to demonstrate what happens when the sensor looses track of an object. This is a good time to reinforce the difference between position, distance, distance traveled, and displacement.

Teacher Tip: When using a motion sensor, it is most common to set the sensor in a fixed position and have the student or object move relative to the sensor. In some instances, it is more appropriate to move the sensor relative to a fixed position, such as a wall. Both methods are completely viable, but you must clarify with students what they will use as a fixed frame of reference.

1. What does the value on the screen represent?

The distance between the motion sensor and the hand

2. How do I make that a position?

Give it a direction and frame of reference (0.5 meters in front of the face of the motion sensor on my desk).

3. If I moved my hand back and forth five times, 0.2 meters away, and then 0.2 back, what is the total distance my hand travelled?

0.4 meters per round trip, five round trips, means my hand traveled approximately 2 meters.

4. If my starting position is 0.5 meters away from the face of the motion sensor, and I move to a final position 1.5 meters from the face of the motion sensor, what is my displacement?

1.0 meters in the positive direction.

Note: In the background it is noted that the direction away from the motion sensor is the positive direction.

Next bring up a graph of Position versus Time. Ask your students to do the following predictions.

Teacher Tip: When using a motion senor to measure a person's movement, it is sometimes easier to have the person hold a target object like a textbook or a basketball. Because the sensor is using an ultrasonic pulse, sound-dampening surfaces like a soft sweater can be difficult for the sensor to track.

5. What do you think the graph will look like if I stand in front of the sensor and collect data for 10 seconds? Sketch your prediction.

The distance will remain constant, and time will increase from 0 to 10 seconds. The graph is a straight line parallel to the *x*-axis.

Stand between one and two meters from the sensor, and have your students estimate your distance from the sensor. Then, collect 10 seconds. of data. Discuss for a moment those predictions that are similar and those that are different.

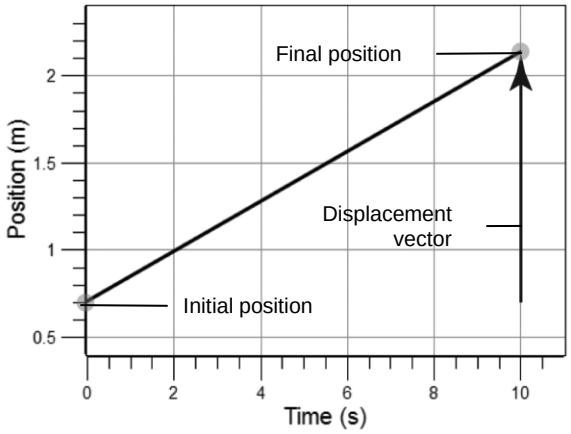
Teacher Tip: If someone willingly shares a significantly different prediction, this can be a good time to work through misconceptions, and review time as the independent variable (*x*-axis) and position as the dependent variable (*y*-axis).

6. What do you think the graph will look like if I move away from the sensor for 10 seconds? Sketch your prediction.

The graph will be a roughly straight line starting at time zero and your initial position with a positive slope.

Stand about one meter from the sensor and have your students estimate your distance from the sensor, then collect 10 seconds. of data while you move slowly and steadily away from the sensor. Briefly discuss those predictions that are similar and those that are different. Then review the key features of the graph.

Teacher Tip: You may want a volunteer to start and stop data collection.



Teacher Tip: Some instructors prefer to start with the Match Graph Challenge available as an EZscreen with Data Studio Software to get students excited about the idea of data collection.

Teacher Tip: Some Instructors prefer to use a cart and track rather than having students acting as the object in motion to reduce the amount of "extra motion" some students bring to the experiment.

Lab Preparation

These are the materials and equipment to set up prior to the lab:

1. Be sure to space the motion sensor stations around the room, and offset the sensors so that they do not directly face each other. The motion sensor will respond to the strongest signal it receives.

Safety

Add these important safety precautions to your normal laboratory procedures:

♦ Make sure you have at least 2 meters of space in front of the motion sensor.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

4	2	1	3
Match the different types of motion you experienced with the different parts of your Position versus Time plot.	Position yourself in front of the motion sensor, and ensure you have adequate space to move.	Connect the motion sensor to the data collection system.	Carefully move and observe Position versus Time graph as you match the motion described.

Procedure with Inquiry

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: Students use the following technical procedures in this activity. The instructions for them (identified by the number following the symbol: "**[diamond]**") are on the storage device that accompanies this manual. Choose the file that corresponds to your PASCO data collection system. Please make copies of these instructions available for your students.

Part 1 - Moving away from the motion sensor

Set Up

1. ☐ Start a new experiment on the data collection system. **[diamond]**(1.2)

2. ☐ Connect the motion sensor to the data collection system, and make sure the motion sensor switch is in the far or "person" position. **[diamond]**(2.1)

3. ☐ Place the motion sensor on a table or rod stand such that you have at least two meters of clear space in front of the sensor and the face of the sensor is level with your midsection.

4. ☐ If you held the motion sensor and pointed it at a fixed position, like a wall, would it change the experiment significantly? Explain?

No, although the wall would now be the fixed position, and therefore the frame of reference, the distance measured would be the same. The fact that, "moving away from the wall is the positive direction," would be the same.

5. ☐ Display Position on the *y*-axis of a graph with Time on the *x*-axis. **[diamond]**(7.1.1)

6. ☐ What are the independent and dependent variables on your graph?

The *x*-axis is the independent variable time, and the *y*-axis is the dependent variable position.

Collect Data

7. ☐ Position yourself approximately 40 cm in front of the motion sensor. You may want to hold a book or ball in front of you as a more easily controlled target.

8. ☐ Have your lab partner start recording a run of data. ◆(6.2)

9. ☐ Stand completely still for 2 seconds, and then carefully move backwards as smoothly as possible (away from the motion sensor) for a few seconds.

10. ☐ Stand still for 2 more seconds, and then have your lab partner stop recording data. ◆(6.2)

Analyze Data

11. ☐ Sketch your graph of Position versus Time in the Data Analysis section.

12. ☐ Annotate your graph in the Data Analysis section with descriptions of your motion at different parts of data collection.

Note: If you will be turning in an electronic document only, you can add notes to the graph on your data collection system ◆(7.1.5)

13. ☐ Find the difference between your initial and final position. ◆(9.2)

$$\text{final} - \text{initial} = 1.8\,\text{m} - 0.5\,\text{m} = 1.3\,\text{m}$$

Part 2 - Moving away from and then toward the motion sensor

Set Up

14. ☐ Use the same set up as in Part 1.

Collect Data

15. ☐ Position yourself approximately 40 cm in front of the motion sensor. You may want to hold a book or ball in front of you as a more easily controlled target.

16. ☐ Have your lab partner start recording a run of data. ◆(6.2)

17. ☐ Carefully move backwards as smoothly as possible (away from the motion sensor) for a few seconds, then stand still for 2 seconds.

18. ☐ Carefully move approximately half way back toward the motion senor, and then have your lab partner stop recording data. ◆(6.2)

Analyze Data

19. ☐ Add this second data run to your graph of Position versus Time in the Data Analysis section.

20. ☐ Annotate your graph in the Data Analysis section with descriptions of your motion at different parts of data collection.

21. ☐ Find the difference between your initial and final position. ◆(9.2)

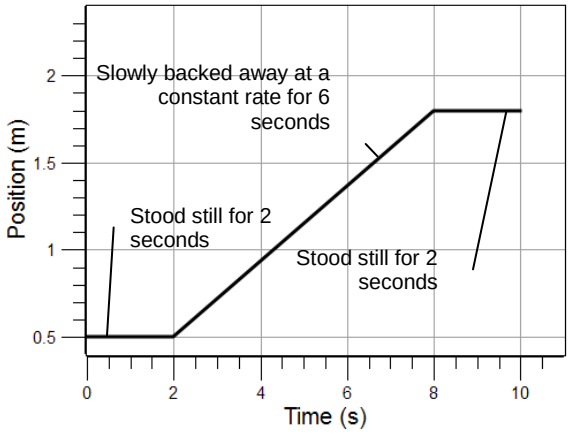
$\text{final} - \text{initial} = 0.9\,\text{m} - 0.5\,\text{m} = 0.4\,\text{m}$

22. ☐ Add a note to your graph with value of the difference. ◆(7.1.5)

23. ☐ Save your data as described by your teacher. ◆(11.1)

Data Analysis

Graph 1: Position versus Time



Analysis Questions

1. From the first data run on your sketch in the Data Analysis section, identify your initial position and your final position?

Initial position was 0.5 meters in front of the motion sensor, and the final position was 1.8 meters in front of the motion sensor (using the sample graph above).

2. For the first run, what was the distance you travelled?

1.3 meters.

3. For the first run what was your displacement?

1.3 meters away from the motion sensor

4. From the second data run on your sketch in the Data Analysis section, identify your initial position and your final position?

Initial position was 0.5 meters in front of the motion sensor, and the final position was 1.2 meters in front of the motion sensor.

5. For the second run, what was the distance you travelled?

1.8 meters, 1.25 meters away from the sensor and .55 meters back toward the sensor.

6. For the second run what was your displacement?

0.7 meters away from the motion sensor.

Synthesis Questions

Use available resources to help you answer the following questions.

1. If you were using a motion sensor to measure the motion of a cart on a track, and the graph of the motion was a straight line starting at 0.2 meter at zero seconds and ending at 1.1 meter at 4 seconds, what is the displacement of the cart?

The displacement of the cart is 0.9 meter away from the motion sensor.

2. At a field meet, a runner in a 2 kilometer event runs on a circular track that is exactly 2 kilometers in circumference so he only has to run one lap. What was his distance traveled in meters, and what was his displacement at the end of the lap?

The runner traveled 2000 meters, but his displacement is zero because he started and stopped at the same point.

3. A graph of Position versus Time of a car travelling down a straight road that starts at a driveway and ends at the post office shows the car travelling 5 miles away from the driveway in 15 minutes, and then 2.5 mile toward the driveway in 5 minutes. What distance did the car travel, and what was the car's final position?

The car travelled 7.5 miles, and its final position is 2.5 miles from the driveway in the direction of the post office.

4. An ant follows a straight chemical trail that starts at its nest to a piece of bread 23 centimeters away. At the end of the day it delivers 10 piece of bread to the nest. What was the total distance the ant travelled in meters, its initial position, and its final position?

The ant travelled 4.6 meters. Its initial position and its final position was the nest.

Multiple Choice Questions

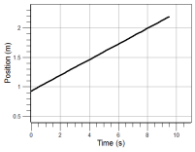
1. When trying to measure a soccer ball's displacement in real time when it is dropped from a height of 1.8 meters, what is the best tool to use?

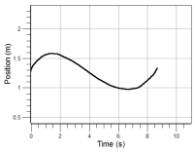
A. Force sensor
B. **Motion sensor**
C. Meter stick
D. Acceleration sensor

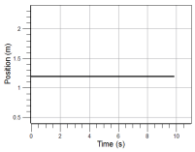
2. A fellow student tells you that her daily walk to school is 6 km. What is this measurement?

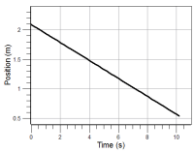
A. Initial position
B. Final position
C. Displacement
D. **Distance travelled**

3. Which graph best represents an object moving away from a motion sensor at a constant speed?

A.  [correct]

B. 

C. 

D. 

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Answers section.

1. Motion is defined as a change in **position** relative to a frame of reference. Distance refers to the length of a **path** between points. In other words, it is the scalar value of length. Position refers to the location (distance and direction) of an object relative to a specific **frame of reference**.

2. Position includes both direction and **distance** from a frame of reference. Frame of reference refers to the location of the observer while measurements are made of position and/or **motion**. The vector displacement only includes the distance and a **direction.**

3. A ranger **traveling** through the woods used a pedometer to determine that he had walked 10 miles along the woodland trails. When he checked his map, he found that he was only a mile and a half north of the point that he started. He had no idea when he started that the trail was so twisted and was surprised that his **distance traveled** could be 10 miles, but his **displacement** was only 1.5 miles north.

Extended Inquiry Suggestions

Competition: using the EZscreen software that comes with Data Studio, take the Match Graph Challenge. Using the first Match Graph, ask each student group do several runs, and then send the student with the highest score to the front of the class to compete against the other groups.

Other graphs: ask your students to try the other graphs available in the EZscreen match activity, and discuss with them the similarities and differences. This is also a good opportunity to introduce the idea that the slope of a Position versus Time graph is related to speed and velocity.