LAB 1: INTRODUCTION TO MOTION

Investigation 1: Distance (Position)-Time Graphs of Your Motion

To find out: How you can measure your motion with a motion detector
How your motion looks as a distance (position)-time graph

Materials: computer-based laboratory system and software
motion detector
Tools for Scientific Thinking High School CD (TSTHS_CD) experiment configuration files
number line on floor in meters (optional)

Introduction: In this investigation, you will use a motion detector to plot a distance (position)-time graph of your motion. As you walk (or jump, or run) the graph on the computer screen displays how far away from the detector you are.

• "Distance" is short for "distance from the motion detector."
• The motion detector is the origin from which distances are measured.
• It detects the closest object directly in front of it (including your arms if you swing them as you walk).
• It will not correctly measure anything closer than 1/2 meter. When making your graphs don't go closer than 1/2 meter from the motion detector.

Activity 1-1: Making Distance-Time Graphs

1. Be sure that the interface is connected to the computer, and the motion detector is plugged into the appropriate port of the interface. Open the experiment file called TL01A1-1a(Distance) to display distance (position) vs. time axes.

2. If you have a number line on the floor and you want the detector to produce readings that agree, stand at the 2-m mark on the number line, begin graphing, and have someone move the detector until the reading is 2 m.

3. Begin graphing and make distance-time graphs for different walking speeds and directions, and sketch your graphs on the axes.
a. Start at the 1/2 meter mark and make a distance-time graph walking *away* from the detector (origin) *slowly and steadily*. Sketch the graph on the right.

b. Make a distance-time graph, walking *away* from the detector (origin) *medium fast and steadily*. Sketch the graph.

c. Make a distance-time graph, walking *toward* the detector (origin) *slowly and steadily*. Sketch the graph.

a. Make a distance-time graph, walking *toward* the detector (origin) *medium fast and steadily*. Sketch the graph.

*Question 1-1:* Describe the difference between the graph you made by walking away slowly and the one made by walking away more quickly.
**Question 1-2:** Describe the difference between the graph made by walking toward and the one made walking away from the motion detector.

**Comment:** It is common to refer to the distance of an object from some origin as the *position* of the object. Since the motion detector is at the origin of the coordinate system, it is better to refer to the graphs you have made as *position-time* graphs rather than *distance-time* graphs.

**Prediction 1-1:** Predict the position-time graph produced when a person starts at the 1-meter mark, walks away from the detector slowly and steadily for 5 seconds, stops for 5 seconds, and then walks toward the detector quickly. Draw your prediction on the left axes using a *dotted* line.

Compare predictions with the rest of your group. See if you can all agree. Draw your group's prediction on the left hand axes using a *solid* line. (Do not erase your original prediction.)

4. Test your prediction. Open the experiment file called **TL01A1-1b(Away and Back)** to set up the software to graph position over a range of 2 m for an time interval of 15 s.

Move in the way described and graph your motion. When you are satisfied with your graph, draw your group's final result on the right axes.

**Question 1-3:** Is your prediction the same as the final result? If not, describe how you would move to make a graph that looks like your *prediction*. 
Activity 1-2: Matching a Position Graph

In this activity you will match a position graph shown on the computer screen.

1. Open the experiment file called TL01A1-2(Position Match). A position graph like that shown below will appear on the screen. Clear any other data remaining from previous experiments.

![Position Graph](image)

Comment: This graph is stored in the computer so that it is persistently displayed on the screen. New data from the motion detector can be collected without erasing the Position Match graph.

2. Move to match the Position Match graph shown on the computer screen. You may try a number of times. Work as a team. Get the times right. Get the distances right. Each person should take a turn.

Question 1-4: What was the difference in the way you moved to produce the two differently sloped parts of the graph you just matched?

Activity 1-3: Other Position-Time Graphs

It will be less confusing if you remove the Position Match graph from the screen before doing the exercises below.

1. Make up your own position-time graph. Use straight lines, no curves. Sketch the graph below with a dashed line. Now see how well someone in your group can duplicate this graph on the screen.
2. Draw the best attempt by a group member to match your position-time graph on the same axes. Use a solid line.

3. Can you make a curved position-time graph? Try to make each of the graphs shown below.

4. Describe how you must move to produce a position-time graph with each of the shapes shown.

Graph 1 answer:

Graph 2 answer:

Graph 3 answer:

**Question 1-5:** What is the general difference between motions that result in a straight-line position-time graph and those that result in a curved-line position-time graph?
INTRODUCTION TO MOTION

Investigation 2: Velocity-Time Graphs of Your Motion

To find out: The connection between velocity and your actual motion
How your motion looks as a velocity-time graph

Materials: computer-based laboratory system and software
motion detector
Tools for Scientific Thinking High School CD (TSTHS_CD) experiment configuration files
number line on floor in meters (optional)

Introduction: You have already plotted your distance (position) from the motion detector as a function of time. You can also plot how fast you are moving. How fast you move is your speed. It is the rate of change of distance with respect to time. Velocity takes into account your speed and the direction you are moving. When you measure motion along a line, velocity can be positive or negative.

Activity 2-1: Making Velocity Graphs

1. Set up to graph velocity. Open the experiment file called TL01A2-1(Velocity Graphs) to set up the axes that follow.

2. Graph your velocity for different walking speeds and directions.
   a. Make a velocity graph by walking away from the detector slowly and steadily. Try again until you get a graph you're satisfied with. You may want to change the velocity scale so that the graph fills more of the screen and is clearer.

   Sketch your result below. (Just draw smooth patterns; leave out smaller bumps that are mostly due to your steps.)
b. Make a velocity graph walking away from the detector medium fast and steadily. Sketch your graph.

c. Make a velocity graph walking toward the detector slowly and steadily. Sketch your graph.

d. Make a velocity graph walking toward the detector medium fast and steadily. Sketch your graph.
Question 2-1: What is the most important difference between the graph made by slowly walking away from the detector and the one made by walking away more quickly?

Question 2-2: How are the velocity-time graphs different for motion away and motion toward the detector?

3. Predict a velocity graph for a more complicated motion and check your prediction.
   a. Each person draw below, using a dotted line, your prediction of the velocity graph produced if you—
      • walk away from the detector slowly and steadily for 10 seconds
      • stop for 4 seconds
      • walk toward the detector steadily about twice as fast as before
   b. Compare predictions and see if you can all agree. Use a solid line to draw in your group prediction.

   Prediction

   +
   
   -1
   
   0
   Velocity (m/s)
   
   0 4 8 12 16 20
   Time (seconds)

4. Do the experiment. (Be sure to adjust the time scale to 20 seconds.) Repeat your motion until you think it matches the description.

   Draw the best graph on the axes below. Be sure the 4-second stop shows clearly.
**Comment:** How fast you move is your speed, the rate of change of distance with respect to time. Velocity implies both speed and *direction*. As you have seen, for motion along a line (the positive x axis) the sign (+ or -) of the velocity indicates the direction. If you move away from the detector (origin) your velocity is positive, and if you move toward the detector, your velocity is negative.

The faster you move *away* from the origin, the larger positive number your velocity is. The faster you move *toward* the origin, the "larger" negative number your velocity is. That is -4 m/s is twice as fast as -2 m/s and both motions are toward the origin.

**Activity 2-2:** Matching a Velocity Graph

In this activity, you will move to match a velocity graph shown on the computer screen.

1. Open the experiment file called **TL01A2-2(Velocity Match)** to display the velocity-time graph shown below on the screen.

2. **Begin Graphing** and move so as to imitate this graph. You may try a number of times. Work as a team and plan your movements. Get the times right. Get the velocities right. Each person should take a turn.

Draw in your group's best match on the axes above.
Question 2-3: Describe how you moved to match each part of the graph.

Question 2-4: Is it possible for an object to move so that it produces an absolutely vertical line on a velocity time graph? Explain.

Question 2-5: Did you run into the motion detector on your return trip? If so, why did this happen? How did you solve the problem? Does a velocity graph tell you where to start? Explain.
INTRODUCTION TO MOTION

Investigation 3: Distance and Velocity Graphs

To find out: The relationship between distance-time and velocity-time graphs.

Materials: computer-based laboratory system and software
motion detector
Tools for Scientific Thinking High School CD (TSTHS_CD) experiment configuration files
number line on floor in meters (optional)

Introduction: You have looked at distance and velocity-time graphs separately. Now you will see how they are related.

Activity 3-1: Predicting Velocity Graphs from Distance Graphs

1. Open the experiment file called TL01A3-1(Vel from Position) to set up the axes shown that follow. Clear any previous graphs.

2. Predict a velocity graph from a distance graph. Carefully study the distance graph shown below and predict the velocity-time graph that would result from the motion. Using a dotted line, sketch your prediction of the corresponding velocity-time graph on the velocity axes.

3. Make the graphs. After each person has sketched a prediction, Begin Graphing, and do your group’s best to make a distance graph like the one shown below. Walk as smoothly as possible.

When you have made a good duplicate of the distance graph, sketch your actual graph over the existing distance-time graph.

Use a solid line to draw the actual velocity graph on the same graph with your prediction. (Do not erase your prediction).
**Question 3-1:** How would the distance graph be different if you moved faster? Slower?

**Question 3-2:** How would the velocity graph be different if you moved faster? Slower?

**Activity 3-2: Estimating and Calculating Velocity**

In this activity, you will estimate an average velocity from the velocity graph in Activity 3-1 and then calculate an average velocity using your distance graph.

1. Estimate your average velocity from your velocity graph in Activity 3-1. You are to estimate an average value for velocity while you were walking away steadily in Activity 3-1. Use the analysis feature in the software to read values of velocity (say ten) from the portion of the velocity graph where your velocity is relatively constant. Use these ten values to calculate the average (mean) velocity. *(Note: your teacher will show you how to read individual data points with the software you are using.)*

<table>
<thead>
<tr>
<th>Velocity values read from graph (m/s):</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

   Average (mean) value of the velocity: _______ m/s

**Comment:** Average velocity during a particular time interval is the change in distance divided by the change in time. By definition, this is also the (average) slope of the distance-time graph for that time period.

As you have observed, the faster you move, the steeper the incline on your distance-time graph. The slope of a distance-time graph is a quantitative measure of this incline, and, therefore, it tells you the velocity of the object.

2. Calculate your average velocity from your distance graph in Activity 3-1. Use the analysis feature of your software that allows you to read the distance and time coordinates for two typical points while you were moving. For a more accurate answer, use two points as far apart as possible but still typical of the motion, and within the same time interval over which you took the ten velocity readings in step (1). *(Note: your teacher might help you decide how to read individual data points with the software you are using.)*
Calculate the change in position between points 1 and 2. Also calculate the corresponding change in time (time interval). Divide the change in position by the change in time to calculate the *average* velocity. Show your calculations below.

<table>
<thead>
<tr>
<th>Point</th>
<th>Position (m)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Change in position (m)</th>
<th>Time interval (s)</th>
<th>Average velocity (m/s)</th>
</tr>
</thead>
</table>

3. Draw in the average velocity you just calculated on the velocity graph in Activity 1.

**Question 3-3:** Is the average velocity positive or negative? Is this what you expected?

**Question 3-4:** Does the average velocity you just calculated from the distance graph agree with the average velocity you estimated from the velocity graph? Do you expect them to agree? How would you account for any differences?

**Activity 3-3:** Predicting Distance Graphs from Velocity Graphs

1. Predict a distance(position)-time graph from a velocity-time graph. Carefully study the velocity graph below. Using a *dotted line*, sketch your *prediction* of the corresponding distance graph on the bottom set of axes. (Assume that you started at the 1-meter mark.)
2. After each person has sketched a prediction do your group's best to duplicate the top graph (velocity-time) by walking. (Reset the Time axis to 0 to 10 sec before you start.)

When you have made a good duplicate of the velocity-time graph, draw your actual result over the existing velocity-time graph.

Use a solid line to draw the actual distance-time graph on the same axes with your prediction. (Do not erase your prediction.)

**Question 3-5:** How can you tell from a velocity-time graph that the moving object has changed direction?

**Question 3-6:** What is the velocity at the moment the direction changes?

**Question 3-7:** Is it possible to actually move your body (or an object) to make the vertical lines on the velocity graph you were trying to match? Why or why not?
Question 3-8: Is it possible to actually move your body (or an object) to make vertical lines on a position-time graph? Why or why not? What would the velocity be for a vertical section of a distance-time graph?

Question 3-9: How can you tell from a position-time graph that your motion is steady (motion at a constant velocity)?

Question 3-10: How can you tell from a velocity-time graph that your motion is steady?