Not-so-Quick Guide to Motion

INTRODUCTION

Because so many topics in physics rely on the motion of an object, it is useful to examine the various properties of motion. If asked, most people would be able to tell that an object is in motion if it changes its position over time. However, there are additional items that are included in motion: position, time, speed, velocity (including constant, non-constant, average, instantaneous), and acceleration (including constant, non-constant, circular). The activities in this, and other QuickGuides, will help you explore these topics. Along the way, you will become familiar with some of the ways to measure different aspects of motion and to display the results.

OBJECTIVES

- Analyze and understand the motion of various situations including, but not limited to: a student walking, a rolling cart, etc.
- Utilize different probes and sensors to make motion measurements
- Predict, sketch, and test position vs. time graphs.
- Predict, sketch, and test velocity vs. time graphs.
- Predict, sketch, and test acceleration vs. time graphs.
- Distinguish between:
  - speed and velocity
  - distance traveled and displacement
  - velocity and acceleration
  - +/- and toward/away
  - average and instantaneous values (like velocity, acceleration)

NECESSARY EQUIPMENT

<table>
<thead>
<tr>
<th>Computer</th>
<th>Motion detector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universal Lab Interface (like LabPro)</td>
<td>meter stick</td>
</tr>
<tr>
<td>Logger Pro</td>
<td>masking tape</td>
</tr>
<tr>
<td>Smart Pulley</td>
<td>Photogates</td>
</tr>
<tr>
<td>Low friction cart with track</td>
<td>Fan for low friction cart</td>
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</tbody>
</table>

PRELIMINARY STEPS

To prepare for the activities in this guide, you will need to do the following:

- Connect the Motion Detector to Dig/Sonic 1 of the LabPro interface.
- Place the motion detector so that it points toward an open space at least 4 m long.
- Prepare the computer for data collection: In Logger Pro, open the file "01a Graph Matching" from the Physics with Computers folder. A graph of position vs. time should appear.
- Test out the equipment! Using Logger Pro, produce a graph of your motion when you walk away from the detector. To do this, stand about 1 m from the Motion Detector and have your lab partner click Collect. Walk slowly away from the Motion Detector when you hear it begin to click. Then walk toward the motion detector. You should see a graph of your motion. If you have difficulty, contact your instructor.
• Make sure to refer to the QuickGuide to the Motion Detector for additional information about and activities with the motion detector.

ACTIVITIES

Make sure to read the following notes before proceeding to specific activities

NOTE I: The following activities will help you become familiar with the motion detector and how it can be used to determine a variety of physical quantities. Do as many of the activities in this and related guides (Motion, Velocity, Acceleration, etc.) so that you can answer questions about motion detector AND about basic physics principles pertaining to the motion of an object, consistent with the objectives stated above. However, should you have some different ideas as to how to accomplish the above objectives, check with your instructor before trying out your ideas.

NOTE II: For the various sections of this activity guide, you will need to make sketches of graphs, describe the motion, and/or include an explanation (complete with graphs and supporting verbiage) as to what happened. You will also be asked to make predictions based on information provided to you.

PART I: Position and Time

Prepare the computer to collect position (d) and time (t) information.

Activity 1

Sketch a d versus t graph of your prediction for each of the following situations in Table I.1.

Table I.1: Walking activities 1

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Graphical Sketch</th>
<th>Explanation/Results/Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing still</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slowly and steadily moving away from the detector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quickly and steadily moving toward the detector</td>
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</tbody>
</table>

Do each of the previous actions by having members of the group walk the prescribed motion.
In the “Explanations” section in Table I.1 above, include your results, including any graphs, explanation and/or discussion about whether or not the actual result was similar to your prediction.

In the space below, write a paragraph summarizing your observations for moving toward and away from the detector, as well as for the difference between “slow” and “quick.”

**Activity 2**

Make the following adjustment to the motion detector: Select “Experiment” from the menu, then select “Set up sensor” to select “LabPro.” You’ll see a picture of the LabPro with the Dig/Sonic 1 box containing the motion detector. When you click on the motion detector icon, you’ll see a menu with one of the items being “Reverse Direction.” Select “Reverse Direction.”

Sketch a d versus t graph of your prediction for each of the following situations in Table I.2.

**Table I.2: Walking activities 2**

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Graphical Sketch</th>
<th>Explanation/Results/Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quickly and steadily moving toward the detector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quickly and steadily moving away from the detector</td>
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<td></td>
</tr>
</tbody>
</table>

Do each of the previous actions by having members of the group walk the prescribed motion.

In the “Explanations” section in Table I.2 above, include your results, including any graphs, explanation and/or discussion about whether or not the actual result was similar to your prediction.

In the space below, summarize your observations for moving toward and away from the detector using the new referencing direction. In particular, distinguish between “+” and “-” directions and “toward and away.”
Activity 3
Describe (predict) the activity required to match the given graphs. Before starting, make sure to indicate in which direction you have designated as positive (+). [Indicate any changes you made to be able to obtain the following graphs.]

Table I.3: Walking activities 3

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Graphical Sketch</th>
<th>Explanation/Results/Discussion</th>
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</thead>
<tbody>
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<td>d</td>
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<tr>
<td></td>
<td>d</td>
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<td></td>
<td>d</td>
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<tr>
<td></td>
<td>d</td>
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</tr>
</tbody>
</table>

Do each of the previous actions by having members of the group walk the prescribed motion.

In the “Explanations” section in Table I.3, include your results, including any graphs, explanation and/or discussion about whether or not the actual result was similar to your prediction.
In the space below, provide an overview of the similarities and differences between speed and velocity. Make sure to include how you could determine speed and velocity from your d vs t graphs.

**Activity 4**
For this activity, you will be using a file from LoggerPro. Open up the file “01b Graph Matching” from the “Physics with Computers” folder. The distance versus time graph should resemble the given graph (Matching Graph I).

In the space provided, describe how you would have to move to reproduce Matching Graph I.

Have each person attempt to reproduce Matching Graph I.

On the graph, sketch your group’s best attempt at matching the graph. In the space provided below, discuss any issues you or your group had in matching the graph and how those issues were resolved.

*Time (and interest) permitting*, repeat the d vs t matching activity given above for file “01c Graph Matching” from the “Physics with Computers” folder. Indicate your responses below.

**PART II: velocity and time**
• Prepare the computer to acquire d vs t information.
• For this part of the activities, you will need to add a second graph, one that displays the velocity of an object as a function of time. Insert a new Graph. Rearrange and adjust the graphs so that you have both “d vs t” and “v vs t” graphs equally displayed at the same time. The best arrangement is to have “d vs t” stacked above “v vs t” so you can compare the two types of graphs for the same time interval.

Activity 1
Describe/predict the position versus time and velocity versus time graphs for the given situations. Place your predictions, including any graphs, in Table II.1. (Be able to provide a verbal description/explanation of the v vs t graph when asked. For example, “Walking with constant velocity is a horizontal line [or line with zero slope] where speed and direction can be found by….”)

Table II.1: Walking activities 1

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Graphical Sketches</th>
<th>Explanation/Results/Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slowly and steadily moving toward the detector</td>
<td></td>
<td></td>
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<tr>
<td>d</td>
<td>t</td>
<td></td>
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</tbody>
</table>

6
Quickly and steadily moving away from the detector.

Do each of the previous actions by having members of the group walk the prescribed motion.

In the “Explanations” section in Table II.1 above, include your results, including any graphs, explanation and/or discussion about whether or not the actual result was similar to your prediction.

Briefly discuss any patterns you may have noticed between the d vs t & v vs t graphs for each situation.

Are there any situations in Table II.1 when the group member was moving with constant velocity? How do you know?
Activity 2 (Optional – to be done if time permits or instructor selects this activity)

This activity is similar to Activity 4 in Part I above. However, your group will generate its own Matching Graph. In Table II.2, sketch in your d vs t graph, description of the motion, and your prediction for the v vs t graph.

Table II.2: Matching graph

<table>
<thead>
<tr>
<th>Activity Description</th>
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</thead>
<tbody>
<tr>
<td></td>
<td><img src="image" alt="Matching Graph - Group" /></td>
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</table>

Match the above graph by having a group member walk the prescribed motion.

In the “Explanations” section in Table II.2, include your results, including any graphs, explanation and/or discussion about whether or not the actual result was similar to your prediction.
**Activity 3**
For the given v vs t Matching Graph shown in Table II.3, describe the motion and predict the d vs t graph.

**Table II.3: Matching graph**

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</table>

Match the above graph by having a group member walk the prescribed motion.

In the “Explanations” section in Table II.3, include your results, additional graphs, and discussion about whether or not the actual result was similar to your prediction.

Describe how you can use information from the graph to determine the **displacement** of an object (how far it has moved from its initial to final locations).

Describe how to determine the **distance traveled** by an object (imagine wearing a pedometer).

Determine the walker’s displacement from 0.5 to 4 sec. Verify your result from the d vs t graph.
Determine the walker’s distance traveled from 0.5 to 8 sec.

Determine the displacement of the walker from 0.5 to 8 sec. Compare with the distance traveled.

Determine the average velocity AND average speed for the walker from 0.5 to 8 sec.

Explain the difference between average speed and average velocity.

**PART III**
- Prepare the computer to acquire d vs t and v vs t information.
- Prepare the motion detector to acquire data for horizontal motion.
- For this part of the activities, include a 3rd graph (a vs t). Make sure it can be displayed at the same time as d vs t and v vs t graphs.

**Activity 1**
Use one of the low friction carts provided. Predict the motion of the cart AFTER you release it from a gentle push. Make sure to indicate direction. Include your predictions for d vs t, v vs t, and a vs t graphs.

**Table III.1: Low friction cart**

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<thead>
<tr>
<th>Activity Description</th>
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</table>
Gently push the cart. Record the cart’s motion AFTER it has been released from your push.

In the “Explanations” section in Table III.1, include your results, including any graphs, explanation and/or discussion about whether or not the actual result was similar to your prediction.

Does the cart move with constant velocity? Support your answer by using information from all three graphs.

**Activity 1b:**
Make sure to examine the same situations outlined Activity 1 using a different probe/sensor. Refer to the QuickGuides on Photogates (including the Smart Pulley) and Accelerometer.

Compare and contrast the results obtained with the motion detector with another probe/sensor, like the Smart Pulley.

**Note:** When done with the probe/sensor, make sure to reconnect the motion detector before Activity 2
**Activity 2**
Add a fan onto the cart. Predict the motion of the cart AFTER you release it from a gentle push. Make sure to indicate direction. Include your predictions for d vs t, v vs t, and a vs t graphs.

**Table III.2: Low friction cart with fan**

<table>
<thead>
<tr>
<th>Activity Description</th>
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Gently push the cart. Record the cart’s motion AFTER it has been released from your push.

Change direction of fan. Repeat the above activity. Record your information on separate paper. Briefly discuss similarities and differences to the previous activity.
Change direction of push. Repeat the above activity. Record your information on separate paper. Briefly discuss similarities and differences to the previous activity.

Change direction of fan. Repeat the above activity. Record your information on separate paper. Briefly discuss similarities and differences to the previous activity.

[Make sure to do all four possibilities: fan in same direction as push; fan in opposite direction as push; push in opposite direction as the first trial, but with cart in same direction; and push in opposite direction as the first trial, but with cart in opposite direction.]

Briefly summarize the four situations. Make sure briefly discuss the similarities and similarities.

Did the cart in any of the four situations move with constant velocity? Support your answer by using information from all three graphs (d vs t, v vs t, and a vs t).

Did the cart in any of the four situations move with constant acceleration? Support your answer by using information from all three graphs (d vs t, v vs t, and a vs t).

Explain the difference between velocity and acceleration.

Further explorations of Motion can be done via the following QuickGuides: Velocity, Acceleration, Motion Detector, Photogates (including the Smart Pulley), and Accelerometer.