Name _____ Date _____

Experiment
33

Graphing Your Motion

Graphs made using a Motion Detector can be used to study motion. In this experiment, you will use a Motion Detector to make graphs of your own motion.

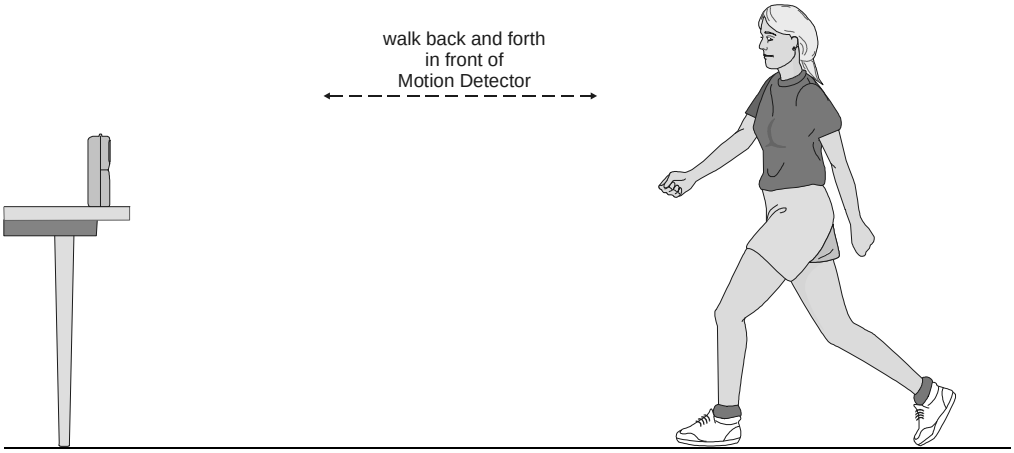
OBJECTIVES

In this experiment, you will

- Use a Motion Detector to measure distance and velocity.
- Produce graphs of your motion.
- Analyze the graphs you produce.
- Match distance *vs*. time and velocity *vs*. time graphs.

MATERIALS

TI-83 Plus or TI-84 Plus graphing calculator
EasyData application
CBR 2 or Go! Motion and direct calculator cable
or Motion Detector and data-collection interface
masking tape
meter stick



PROCEDURE

Part I Distance *vs*. Time Graphs

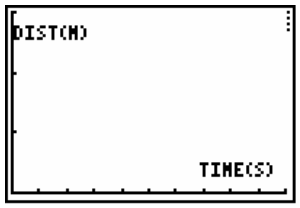
1. Fasten a Motion Detector to a tabletop facing an area free of furniture and other objects. The Motion Detector should be at a height of about 15 cm above your waist level.
2. Use short strips of masking tape on the floor to mark the 1 m, 2 m, 3 m, and 4 m distances from the Motion Detector.

3. Connect the Motion Detector.

   a. Open the pivoting head of the Motion Detector.
   b. If the Motion Detector has a sensitivity switch, set it to Normal.
   c. Turn on the calculator and connect it to the Motion Detector. (This may require the use of a data-collection interface.)

4. Set up EasyData for data collection.
   a. Start the EasyData application, if it is not already running.
   b. Select File from the Main screen, and then select **New** to reset the application.

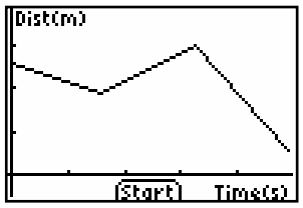
5. Explore making distance *vs*. time graphs.
   a. Stand at the 1.0 m mark, facing away from the Motion Detector.
   b. Signal your partner to select Start.
   c. Slowly walk to the 2.5 m mark and stop.
   d. When data collection ends, a graph of distance versus time will be displayed.
   e. Sketch your graph on the empty graph provided at the right.
   f. Select Main to return to the Main screen.



6. Repeat Step 5 while walking faster. Sketch your new line on the same graph.

Part II Matching Distance *vs*. Time Graphs

7. Set up the calculator and interface for distance *vs*. time graph matching.
   a. Select Setup from the Main screen, then select **Distance Match**.
   b. Select Start, then OK, then Next after reading the Distance Match information.
   c. EasyData randomly generates matching graphs like the one shown here; your graph may be different.



8. Match the first distance *vs*. time graph.
   a. Examine the graph and plan what you will do to match it. Note: The vertical axis runs from 0 to 3 meters. Data will be collected for 10 seconds.
   b. Take your starting position in front of the Motion Detector.
   c. When you are ready to begin matching, signal your partner to select Start.
   d. Move according to your plan.
   e. Examine the graph of the results.
   f. Sketch your results on Graph 1 below. Describe what you had to do to match the first graph. Sketch the graph you were matching and the graph of your motion.
   g. If you want to repeat the first match, select Retry. If you are ready to move on to a second graph, select New.

9. Repeat Step 8 until you have matched a total of three distance *vs*. time graphs.

Name _____ Date _____

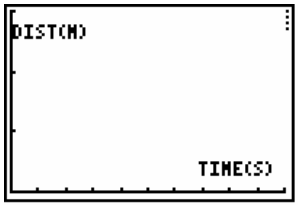
PROCESSING THE DATA (Part I)

1. Describe the differences between your two graphs.

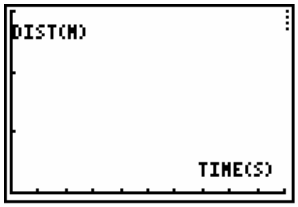
PROCESSING THE DATA (Part II)

2. Sketch your results in the empty graphs provided below. Describe what you had to do to match each of the graphs.

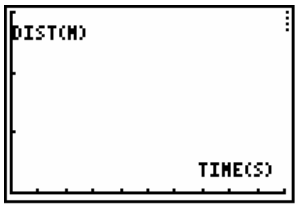
Graph	What I did to match my graph:



Graph 1



Graph 2



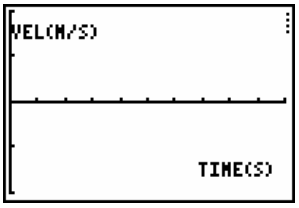
Graph 3

Part III Velocity *vs*. Time Graphs

10. Explore making velocity *vs*. time graphs.
    a. Select [File] from the Main screen, and then select **New** to prepare to collect new data.
    b. Take a starting position at the 1 m mark in front of the Motion Detector.
    c. Signal your partner to select [Start].
    d. Stand still for one second, and then walk to the 3 m mark (away from the Motion Detector) at constant velocity.
    e. Stand still for one second, then walk backwards to the 1 m mark (toward the Motion Detector) at constant velocity.
    f. When data collection ends, a graph of distance versus time will be displayed. To see the velocity graph, select [Plots], then select **Vel(m/s) vs Time**.
    g. Sketch your velocity *vs*. time graph below.

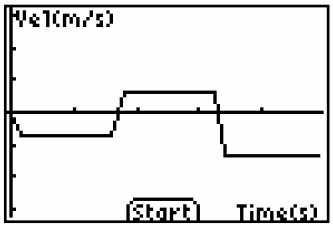
PROCESSING THE DATA (Part III)

3. How does this velocity *vs*. time graph differ from your distance *vs*. time graphs made in Steps 5 and 8?



Part IV Matching Velocity *vs*. Time Graphs

11. Set up the calculator and interface for velocity *vs*. time graph matching.
    a. Select [Main] to return to the Main screen.
    b. Select [Setup] from the Main screen, then select **Velocity Match**.
    c. Select [Start], then [OK] to overwrite the latest run.
    d. Select [Next] after reading the Graph Match information to display a randomly generated velocity *vs*. time graph.



12. Match the first velocity *vs*. time graph.
    a. Examine the graph and plan what you will do to match it. Data will be collected for ten seconds.
    b. Take your starting position in front of the Motion Detector.
    c. Signal your partner to select [Start].
    d. Move according to your plan.
    e. Examine the graph of the results.
    f. Sketch your results on Graph 1 below. Describe what you had to do to match the first graph. Show the graph you were matching and the graph of your motion.
    g. If you want to repeat the first match, select [Retry]. If you are ready to move on to a second graph, select [New].

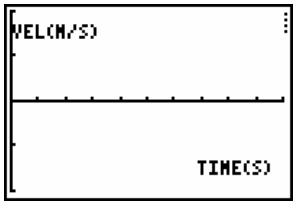
13. Repeat Step 12 for a second velocity vs. time graph.

Name _____ Date _____

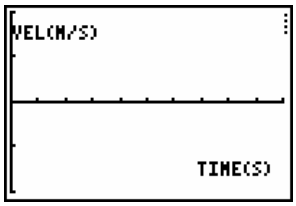
PROCESSING THE DATA (Part IV)

4. Sketch your results in the empty graphs provided below. Describe what you had to do to match each of the graphs.

Graph	What I did to match my graph:



Graph 1



Graph 2

EXTENSIONS

1. Create a graph-making challenge. Sketch a distance *vs*. time graph on a piece of paper and challenge another student in the class to match your graph. Have the other student challenge you in the same way.

2. Create a velocity *vs*. time challenge in a similar manner.

TEACHER INFORMATION

Graphing Your Motion

1. This activity can be performed with calculators from the TI-83 Plus or TI-84 Plus families and a LabPro or CBL 2. It cannot be performed with EasyLink because Motion Detectors cannot be plugged into the EasyLink.

   There are four Motion Detectors that can be used for this lab activity. Listed below are the best methods for connecting your type of Motion Detector. Optional methods are also included:

   Go! Motion: This sensor does not include any cables to connect to a graphing calculator. The cable that is included with it is intended for connecting to a computer's USB port. To connect a Go! Motion to a TI graphing calculator, select one of the options listed below:

   Option I–the Go! Motion connects to a CBL 2 or LabPro using the Motion Detector Cable (order code: MDC-BTD) sold separately by Vernier Software & Technology.

   Option II–the Go! Motion connects to the graphing calculator's I/O port using an extended length I/O cable (order code: GM-CALC) sold separately by Vernier Software & Technology.

   Option III–the Go! Motion connects to the TI-84 Plus graphing calculator's USB port using a Calculator USB cable (order code: GM-MINI) sold separately by Vernier Software & Technology.

   CBR 2: The CBR 2 includes two cables: an extended length I/O cable and a Calculator USB cable. The I/O cable connects the CBR 2 to the I/O port on any TI graphing calculator. The Calculator USB cable is used to connect the CBR 2 to the USB port located at the top right corner of any TI-84 Plus calculator.

   
   I/O cable

   
   USB cable

   Optionally, the CBR 2 can connect to a CBL 2 or LabPro using the Motion Detector Cable. This cable is not included with the CBR 2, but can be purchased from Vernier Software & Technology (order code: MDC-BTD).

   Vernier Motion Detector: Connect the Vernier Motion Detector to a CBL 2 or LabPro using the Motion Detector Cable included with this sensor. The CBL 2 or LabPro connects to the calculator using the black unit-to-unit link cable that was included with the CBL 2 or LabPro.

   
   MDC cable

   CBR: Connect the CBR directly to the graphing calculator's I/O port using the extended length I/O cable that comes with the CBR.

   Optionally, the CBR can connect to a CBL 2 or LabPro using a Motion Detector Cable. This cable is not included with the CBR, but can be purchased from Vernier Software & Technology (order code: MDC-BTD).

   
   I/O cable

2. This experiment may be the first time your students use the Motion Detector. A little coaching on its use now will save time later in the year as the Motion Detector is used in many experiments. Here are some hints for effective use of the Motion Detector.

   - In using the Motion Detector, it is important to realize that the ultra sound is emitted in a cone about 30° wide. Anything within the cone of ultrasound can cause a reflection and possibly an accidental measurement. A common problem in using Motion Detectors is getting unintentional reflections from a desk or chair in the room.
   - Often unintended reflections can be minimized by tilting the Motion Detector slightly.
   - If you begin with a velocity or acceleration graph and obtain a confusing display, switch back to a distance graph to see if it makes sense. If not, the Motion Detector may not be properly targeting the target.
   - The Motion Detector does not properly detect objects closer than 0.15 m. The maximum range is about 6 m, but stray objects in the wide detection cone can be problematic at this distance. There is a switch underneath the tilting head. Tilt up the head and adjust the switch to the Normal mode.

   - Sometimes a target may not supply a strong reflection of the ultrasound. For example, if the target is a person wearing a bulky sweater, the resulting graph may be inconsistent.
   - If the velocity and acceleration graphs are noisy, try to increase the strength of the ultrasonic reflection from the target by increasing the target's area.

3. You may want to have your students hold a large book in front of them as they walk in front of the Motion Detector. This will produce better graphs because it smoothes out the motion.

ACKNOWLEDGMENT

We wish to thank Rick Sorensen for his help in developing this experiment.

SAMPLE RESULTS

Distance vs. Time

Matching Distance vs. Time

Velocity vs. Time

Matching Velocity vs. Time

ANSWERS TO QUESTIONS

Answers have been removed from the online versions of Vernier curriculum material in order to prevent inappropriate student use. Graphs and data tables have also been obscured. Full answers and sample data are available in the print versions of these labs.