Graph Matching

One of the most effective methods of describing motion is to plot graphs of distance, velocity, and acceleration vs. time. From such a graphical representation, it is possible to determine in what direction an object is going, how fast it is moving, how far it traveled, and whether it is speeding up or slowing down. In this experiment, you will use a Motion Detector to determine this information by plotting a real time graph of your motion as you move across the classroom.

The Motion Detector measures the time it takes for a high frequency sound pulse to travel from the detector to an object and back. Using this round-trip time and the speed of sound, the CBL can determine the distance to the object; that is, its position. It can then use the change in position to calculate the object’s velocity and acceleration. All of this information can be displayed in a graph. A qualitative analysis of the graphs of your motion will help you understand the concepts of kinematics.

OBJECTIVES

• Analyze the motion of a student walking across the room.
• Predict, sketch, and test distance vs. time kinematics graphs.
• Predict, sketch, and test velocity vs. time kinematics graphs.

MATERIALS

TI-82, 83, 86, 89, 92, or 92 Plus
CBL System
PHYSICS program loaded in calculator

Vernier Motion Detector
meter stick
masking tape
PRELIMINARY QUESTIONS

1. Use a coordinate system with the origin at far left and positive distances increasing to the right. Sketch the distance vs. time graph for each of the following situations:
   - An object at rest
   - An object moving in the positive direction with a constant speed
   - An object moving in the negative direction with a constant speed
   - An object that is accelerating in the positive direction, starting from rest

2. Sketch the velocity vs. time graph for each of the situations described above.

PROCEDURE

Part I Preliminary Experiments

1. Place the Motion Detector so that it points toward an open space at least 4 m long. Use short strips of masking tape on the floor to mark the origin and the 1 m, 2 m, and 3 m distances from the Motion Detector.

2. Connect the Vernier Motion Detector to the SONIC port of the CBL unit. Use the black link cable to connect the CBL unit to the calculator. Firmly press in the cable ends.

3. Set up the calculator and CBL for the Motion Detector. Start the PHYSICS program and proceed to the MAIN MENU.
   - Select SET UP PROBES from the MAIN MENU.
   - Select ONE as the number of probes.
   - Select MOTION from the SELECT PROBE menu.

4. Set up the calculator and CBL for data collection.
   - Select COLLECT DATA from the MAIN MENU.
   - Select TIME GRAPH from the DATA COLLECTION menu.
   - Enter “0.1” as the time between samples, in seconds.
   - Enter “99” as the number of samples (the CBL will collect data for about 10 seconds).
   - Press ENTER, then select USE TIME SETUP to continue. If you want to change the sample time or sample number, select MODIFY SETUP instead.
   - Select LIVE DISP from the TIME GRAPH menu.
   - Enter “0” for the Ymin, so that the y-axis will start at zero meters.
   - Enter “2.5” for the Ymax, so that the y-axis will end at 2.5 meters.
   - Enter “0.5” for Yscl, so that the y-axis will have a tick mark every half meter.

5. Make a graph of your motion when you walk away from the detector with constant velocity. To do this, stand about 1 m from the Motion Detector and have your lab partner press ENTER. Walk slowly away from the Motion Detector when you hear it begin to click. The graph will be drawn as you walk. After data collection is complete, press ENTER to see a rescaled version of the graph.

6. Sketch what the distance vs. time graph will look like if you walk faster. Check your prediction with the Motion Detector. To take more data, press ENTER, and select YES from the REPEAT? menu.

7. Try to match the shape of the distance vs. time graphs that you sketched in the Preliminary Questions section by walking in front of the Motion Detector.
Part II  Distance vs. Time Graph Matching

8. Return to the main menu by selecting NO from the REPEAT? menu.

9. The PHYSICS program can generate random target distance graphs for you to match, such as the sample shown here. Your graph may be different.
   • Select COLLECT DATA from the MAIN MENU.
   • Select GRAPH MATCH from the DATA COLLECTION menu.
   • Select DISTANCE MATCH from the GRAPH MATCH menu.
   • Note the screen instructions, and press ENTER.

10. Write down how you would walk to produce this target graph. Sketch or print a copy of the graph. The vertical axis runs from 0 to 2.5 meters, and the time axis runs from 0 to 10 seconds.

11. To test your prediction, choose a starting position and stand at that point. Start data collection by pressing ENTER. When you hear the Motion Detector begin to click, walk in such a way that the graph of your motion matches the target graph on the calculator screen.

12. If you were not successful, repeat the process until your motion closely matches the graph on the screen. To repeat with the same graph, press ENTER and select SAME MATCH from the OPTIONS menu. Print or sketch the graph with your best attempt.

13. Perform a second distance graph match (Steps 10-12) by pressing ENTER and selecting NEW MATCH from the OPTIONS menu.

14. Answer the Analysis questions for Part II before proceeding to Part III.

Part III  Velocity vs. Time Graph Matching

15. The PHYSICS program can also generate random target velocity graphs for you to match, such as the sample graph shown here. Your graph may be different.
   • Select RETURN TO MAIN from the OPTIONS menu.
   • Select COLLECT DATA from the MAIN MENU.
   • Select GRAPH MATCH from the DATA COLLECTION menu.
   • Select VELOCITY MATCH from the GRAPH MATCH menu.
   • Note the screen instructions, and press ENTER.

16. Write down how you would walk to produce this target graph. Sketch or print a copy of the graph. The vertical axis runs from −0.5 m/s to +0.5 m/s, and the time axis runs from 0 to 10 seconds.

17. To test your prediction, choose a starting position and stand at that point. Start data collection by pressing ENTER. When you hear the Motion Detector begin to click, walk in such a way that the graph of your motion matches the target graph on the calculator screen. It will be more difficult to match the velocity graph than it was for the distance graph.

18. If you were not successful, repeat the process until your motion closely matches the graph on the screen. To repeat with the same graph, press ENTER and select SAME MATCH. Print or sketch the graph with your best attempt.
19. Perform a second velocity graph match (Steps 16-18) by pressing [ENTER] and selecting NEW MATCH from the OPTIONS menu.

20. Remove the masking tape strips from the floor.

**ANALYSIS**

**Part II  Distance vs. Time Graph Matching**

1. Describe how you walked for each of the graphs that you matched.

2. Explain the significance of the slope of a distance vs. time graph. Include a discussion of positive and negative slope.

3. What type of motion is occurring when the slope of a distance vs. time graph is zero?

4. What type of motion is occurring when the slope of a distance vs. time graph is constant?

5. What type of motion is occurring when the slope of a distance vs. time graph is changing? Test your answer to this question using the Motion Detector.

6. Return to the procedure and complete Part III.

**Part III  Velocity vs. Time Graph Matching**

7. Describe how you walked for each of the graphs that you matched.

8. What type of motion is occurring when the slope of a velocity vs. time graph is zero?

9. What type of motion is occurring when the slope of a velocity vs. time graph is not zero? Test your answer using the Motion Detector.

**EXTENSIONS**

1. Create a graph-matching 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.