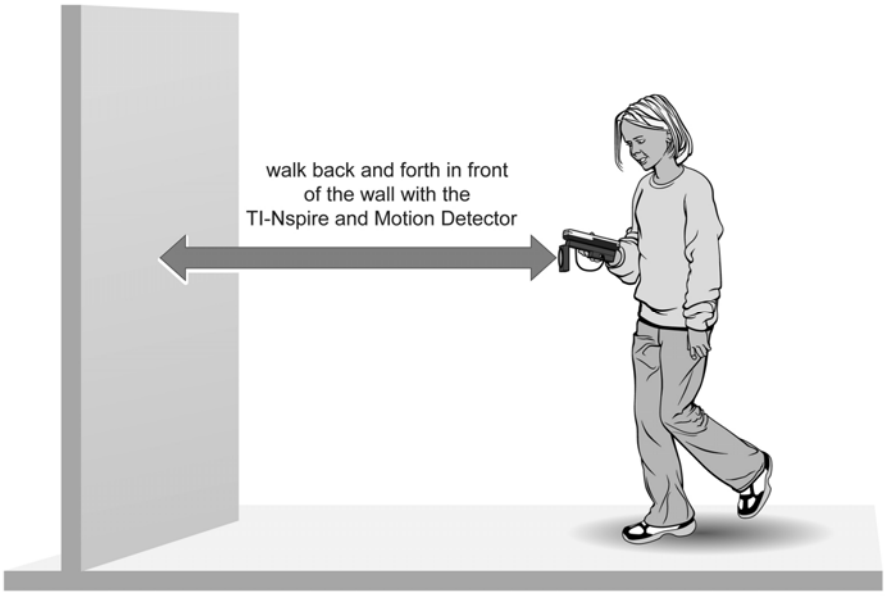
Graph Matching

One of the most effective methods of describing motion is to plot graphs of position, 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 distance to the object can be determined; that is, its position. The change in the position data can then be used 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 position *vs*. time kinematics graphs.
- Predict, sketch, and test velocity *vs*. time kinematics graphs.

MATERIALS

TI-Nspire handheld **or**
computer and TI-Nspire software
CBR 2 **or** Go! Motion, **or**
Motion Detector and data-collection interface
meter stick
masking tape

PRE-LAB QUESTIONS

1. Sketch the position *vs*. time graph for each of the following situations. Use a coordinate system with the origin at far left and positive distances increasing to the right.
   a. An object at rest
   b. An object moving in the positive direction with a constant speed
   c. An object moving in the negative direction with a constant speed
   d. 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.

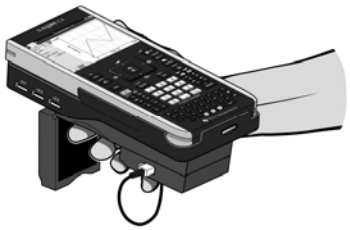
PROCEDURE

1. Find an open area at least 4 m long in front of a wall. Use short strips of masking tape on the floor to mark distances of 1 m, 2 m, and 3 m from the wall. You will be measuring distances from the Motion Detector in your hand to the wall.
2. If your Motion Detector has a switch, set it to Normal. Connect the Motion Detector to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer. (If you are using a CBR 2 or Go! Motion, you do not need a data-collection interface.)

3. Choose New Experiment from the Experiment menu. Choose Collection Setup from the Experiment menu. Enter **10** as the experiment duration in seconds. The number of points collected should be 201. Select OK.
4. Click the Graph View tab (). Choose Show Graph ► Graph 1 from the Graph menu. Only the Position vs. Time Graph will be displayed.

Part I Preliminary Position *vs*. Time Experiments

5. Open the hinge on the Motion Detector. When you collect data, hold the Motion Detector so the round, metal detector is always pointed directly at the wall. Sometimes you will have to walk backwards.



6. Monitor the position readings. Move back and forth and confirm that the values make sense.
7. Make a graph of your motion when you walk away from the wall with constant velocity. To do this, stand about 1 m from the wall, start data collection (), and walk backward, slowly away from the wall.
8. Use the Draw Prediction tool (from the Analyze menu) to show what the distance *vs*. time graph will look like if you walk faster. Check your prediction with the Motion Detector. Start data collection () when you are ready to begin walking.
9. Try to match the shape of the distance *vs*. time graphs that you sketched in the Preliminary Questions section by walking back and forth in front of the wall.

Part II Position *vs*. Time Graph Matching

10. Choose New Experiment from the Experiment menu. Choose Collection Setup from the Experiment menu. Enter **10** as the experiment duration in seconds. The number of points collected should be 201. Select OK.

11. Click the Graph View tab ( ). Choose Motion Match ► New Position Match from the Analyze menu. A target graph will be displayed for you to match.

12. Write down how you would walk to reproduce the target graph. Sketch or print a copy of the graph.

13. To test your prediction, choose a starting position. Start data collection ( ), then walk in such a way that the graph of your motion matches the target graph on the screen.

14. If you were not successful, try step 13 again. Repeat this process until your motion closely matches the graph on the screen. Print or sketch the graph with your best attempt.

15. Perform a second graph match by choosing Motion Match ► New Position Match from the Analyze menu. This will generate a new target graph for you to match.

16. Answer the Analysis questions for Part II.

Part III Preliminary Velocity *vs*. Time Experiments

17. Insert a new Problem into your TI-Nspire document and add a DataQuest App to the problem.

18. Choose New Experiment from the Experiment menu. Choose Collection Setup from the Experiment menu. Enter **10** as the experiment duration in seconds. The number of points collected should be 201. Select OK.

19. Click the Graph View tab ( ). Choose Show Graph ► Graph 2 from the Graph menu. Only the Velocity vs. Time Graph will be displayed.

20. Make a graph of your motion when you walk away from the wall with constant velocity. To do this, stand about 1 m from the wall, start data collection ( ), and walk backward, slowly away from the wall.

21. Use the Draw Prediction tool (from the Analyze menu) to show what the velocity *vs.* time graph will look like if you move toward the wall at the same speed you walked away from the wall. Check your prediction with the Motion Detector. Start data collection ( ) when you are ready to begin walking.

22. Try to match the shape of the velocity *vs*. time graphs that you sketched in the Preliminary Questions section by walking back and forth in front of the wall.

Part IV Velocity *vs*. Time Graph Matching

23. Choose New Experiment from the Experiment menu. Choose Collection Setup from the Experiment menu. Enter **10** as the experiment duration in seconds. The number of data points collected will be 201. Select OK.

24. Click the Graph View tab ( ). Choose Motion Match ► New Velocity Match from the Analyze menu. A target graph will be displayed for you to match. Choose Window Settings from the Graph menu, then enter **–2** for Y Min and **2** for Y Max.

25. Write down how you would walk to produce this target graph. Sketch or print a copy of the graph.

26. To test your prediction, choose a starting position and stand at that point. Start data collection (), then walk in such a way that the graph of your motion matches the target graph on the screen. It will be more difficult to match the velocity graph than it was for the position graph.

27. If you were not successful, try Step 26 again. Repeat this process until your motion closely matches the graph on the screen. Print or sketch the graph with your best attempt.

28. Perform a second velocity graph match by choosing Motion Match ► New Velocity Match from the Analyze menu. This will generate a new target velocity graph for you to match.

29. Remove the masking tape strips from the floor.

QUESTIONS

Part II Position *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 position *vs*. time graph. Include a discussion of positive and negative slope.

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

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

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

6. Return to the procedure and complete Parts III and IV.

Part IV 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 position *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.