Name: ___________________________________

Partner(s): ________________________________

1118 section: _______

Desk # _____________

Date: _________________

One Dimensional Motion

Purpose

1. To learn about two ways to describe motion along a straight line: words and graphs.
2. To acquire an understanding of position, speed and velocity.
3. To see how graphs can be used to describe changes in position and velocity.

Introduction and Theory

In order to use physics to describe motions which involve a change in speed or direction, you must learn how to describe them both graphically and mathematically. The study of the representation of motions using mathematical equations and graphs is known as kinematics. Describing the motion is not always easy; a complex example would be a cloud in the sky changing its size and shape as it moves. In this lab, we will only study one-dimensional motions: motions confined to a straight line.

The activities in this lab use a computer-based laboratory system consisting of a microcomputer, an electronic interface, a motion detector and special software to help you study motion. The software can use a programmed set of rules to measure your position at a specific time, and calculate two other quantities that are used to describe motion from these position and time measurements. These are velocity and acceleration. The software then graphs all of these quantities as functions of time.

The Ultrasonic Motion detector

The ultrasonic motion detector sends out a series of sound pulses that are beyond our hearing. These pulses reflect from nearby objects and some of the sound pulses return to the sensor. The computer records the time it takes for reflected sound waves to return to the sensor and then, by knowing the speed of sound in air, figures out how far away the reflecting object is from the sensor.

Things to Watch Out for When Using a Motion detector

- The detector's range is between 0.5 m and 4 m. Outside of this range, the sensor is not reliable. A series of very "spiky" lines or a flat line will tell you that you are out of range.
- The ultrasonic waves spread out in a cone of about 15° as they travel. They will "see" the closest object. Be sure there is a clear path between the object whose motion you want to track and the motion detector.
- The motion detector is very sensitive and will detect slight motions. Some objects, like bulky sweaters, are good sound absorbers and may not be "seen" very well by a motion detector. You may want to hold a book in front of yourself if you have on loose clothing.
- There is a slight (up to 1 second) delay between measuring your position and showing it on screen. You may have to start or stop moving sooner to account for this delay to get the best match of the graphs.
- You will probably find that walking backwards while facing the monitor will help you to more closely match your motions to the trace on the screen.

Position vs Time Graphs of Your Motion

After completing the next few activities, you should

- be able to look at a position vs time graph and describe the motion of an object. To describe the motion, you should give your direction of movement (move away or toward the detector), your speed (fast, slow, or at rest) and how your speed changes (increasing, decreasing, or constant).

- be able to sketch or describe a graph of an object's motion after watching it move or knowing how it moved. To describe a graph, you should state whether it is a straight line or a curve, and where the line is drawn. For straight lines, describe whether the slope is positive (angled up), negative (angled down), or zero (flat), and whether the straight line is steep or not. For curves, describe the shape of the curve.

Note: For these computer-based position measurements: the motion detector is the origin – that is, the reference point for all position graphs. Since the motion detector cannot tell right from left, the motion detector defines the positive direction to be away from itself.

- Plug the motion detector into a DIGI/Sonic channel on the Vernier interface box. Place the motion detector on the desk, so that it points toward an open space 3 to 4 m long.

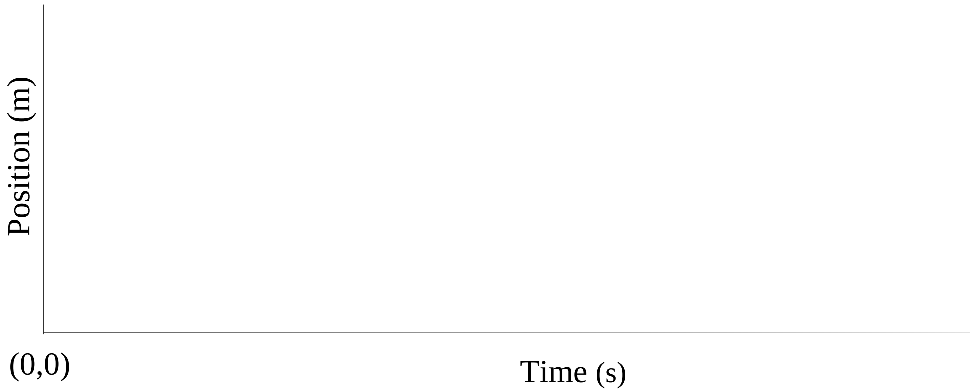
- Start the LoggerPro program from the desktop icon. The program will automatically detect that the motion detector is attached and display 2 graphs: position vs time and velocity vs time. For now, we do NOT want these graphs. Open the file: *_Physics with Vernier\01a Graph Matching.cmbl*. This file will display one position vs time graph.

You are ready to collect data for activity #1.

Activity #1: Interpreting Position Graphs

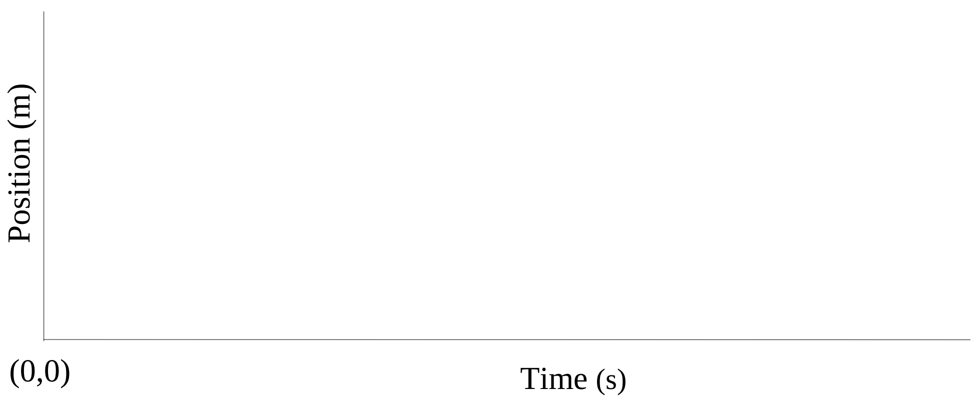
1a. Select "Experiment"…"Data Collection" from the menu and set the length of the data collection to 15 s. Data collection starts when you press the "Collect" button, and you should hear the detector clicking while it is collecting data.

1b. Make a position-time graph: Stand at least 0.5 m away from the motion detector and stand still for about 5 s, then walk slowly and steadily (at a constant speed) away for about 5 s and then walk away at a faster, but still constant rate for the remaining 5 s.



- Draw the trace from the screen.
- On each of the 3 line segments, describe your motion for that segment in words.

1c. Make another position-time graph. This time, stand about 3 m away from the motion detector and stand still for about 5 s, then move slowly and steadily towards the sensor for about 5 s, then move faster but still steadily towards for another 5 s.



- Draw the trace from the screen.
- On each of the 3 line segments, describe your motion for that segment in words.

1d. What is the difference between walking slowly and quickly, both at a constant speed? Answer in terms of the magnitude of the slope.

Slowly: ______________________________. Quickly: ___________________________________.

1e. What is the difference between walking toward the motion detector and away from the detector? Answer in terms of the sign of the slope.

Towards: ______________________________. Away from: _________________________________.

To summarize, the slope of the position-time graph represents the ________________ of the motion.

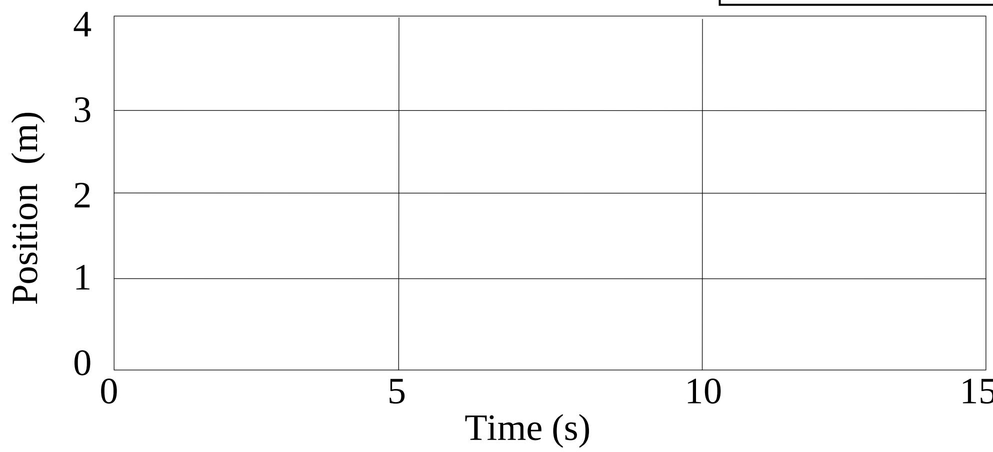
Predicting the Shapes of Position vs Time Graphs

A good way to verify that you understand how to interpret position vs time graphs is to predict the shape of a graph for a set of motions that can be described in words. You can then carry out the motions to verify your prediction.

Activity #2: Predicting a Position vs Time Graph

2a. Sketch your prediction on the following graph using a dashed line. Suppose you are to start 2.0 m in front of the sensor and walk away slowly and steadily for 6 s, stop for 3 s, and then walk toward the sensor quickly for 6 s.

Prediction: dashed line
Actual motion: solid line



2b. Test your prediction by attempting to produce a graph that looks like the one you just drew. Move in the way described and sketch the trace of your actual motion with a solid line, on the same graph that you just drew.

2c. Is your prediction roughly the same as the actual result? Yes No

If NO, describe how you would move to make a graph that looks more like your prediction.

Activity #3: Matching Position vs Time Graphs

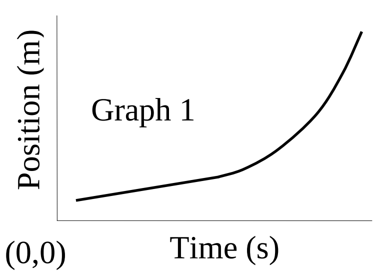
Let's turn the activity you just did inside out. We would like you to look at a graph of a completed motion and then describe in words the motion you think it depicts. Then you should be able to reproduce the motion you described.

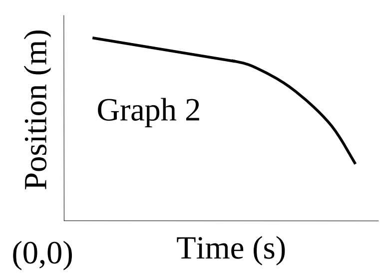
In this activity, you will try to move to match a position graph shown on the computer screen. To do this, Open the file: *_Physics with Vernier\01b Graph Matching.cmbl.* The screen should now show a graph with a trace already on it. This is what you are going to try to match.

3a. Below, describe in your own words how you plan to move in order to match this trace, giving specific times.

3b. Now try to move to match the graph shown. You will probably have to try this a number of times. It helps if you turn the monitor so that the person moving can see the screen when they are moving. Get the times and positions right. Each person in your group should do their own match. You will not learn very much by just watching!

3c. Make position vs time graphs like those shown below. Note: Before trying to reproduce these shapes, start with a new blank graph by reopening *01a Graph Matching.cmbl*.





3d. In the space provided below, describe how you would have to move in order to produce a position vs time graph with the shapes shown:

Graph 1:

Graph 2:

3e. In general, what is the difference between motions that result in a straight line position vs time graph and those that result in a curved line position vs time graph?

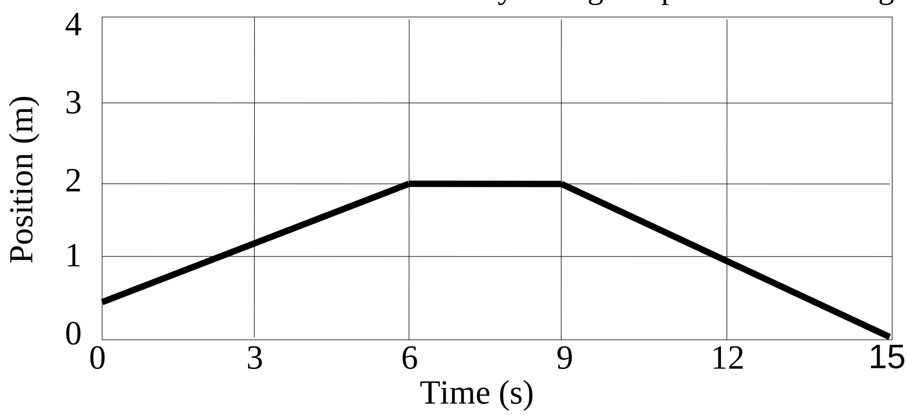
Straight line:

Curved line:

Describing Velocity with Words and Graphs

Describing Speed and Direction Changes Graphically

You have already created position vs time graphs for your body motions. Now, suppose you were a race car driver who is more interested in recording the direction AND the speed of your car, based originally on position measurements. Think about how you might represent this on a graph.



The motion of a race car

After examining the graph in the above figure, answer the following questions and see if you can devise a sensible method for representing both speed and direction vs time graphically.

Activity #4: Drawing a Speed/Direction Graph

4a. What is the speed of the car between 0 and 6s? Show all the numbers used in all of the following calculations. Express all numerical results to 2 significant figures, or exact fractions.

4b. What is its direction in this time period?

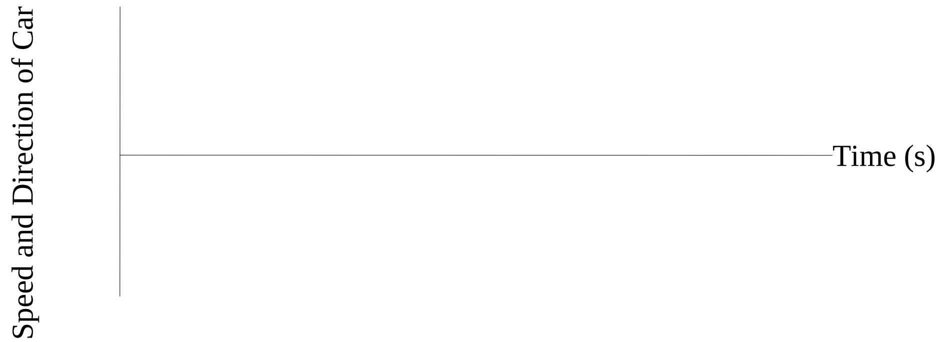
4c. What is the speed of the car between 6 and 9 s?

4d. What is its direction?

4e. What is the speed of the car between 9 and 15 s? (Note that the speed is always positive.)

4f. What is its direction?

4g. Graph your result based on your answers on page 6 (<u>both the speed and direction of the car</u>) on the graph frame below. Label both axes with numbers and units!



4h. Summarize the method to graphically represent both the speed and the direction of motion in the table below. Describe where and how you would draw the lines on the graph (as in Question **4g**) instead of giving specific numbers.

Motion	Description of graphical representation
Object is moving away from the detector at constant speed.	
Object is stopped.	
Object is moving toward the detector at constant speed.	

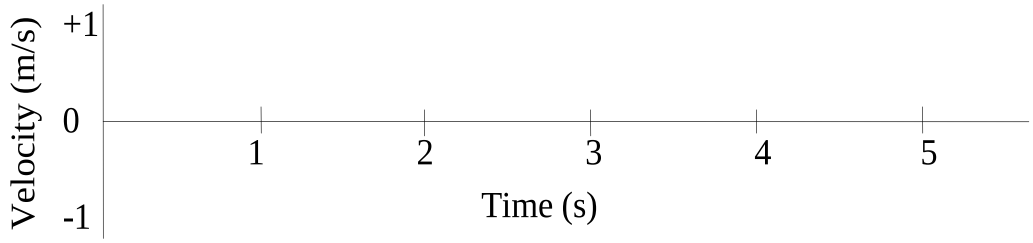
Velocity Graphs and the Definition of Velocity

Velocity represents both the direction and speed of motion of an object. A positive or negative sign signifies the direction the object is moving. Our motion-recording software can be set to display graphs of velocity vs time, by using mathematical rules that are programmed into the motion software. In the next few activities, you will observe the motion of your body and try to discover some characteristics of those rules. These graphs are tricky to interpret after working with position/time graphs. You must switch to thinking about what is happening to the object's velocity, rather than just where it is.

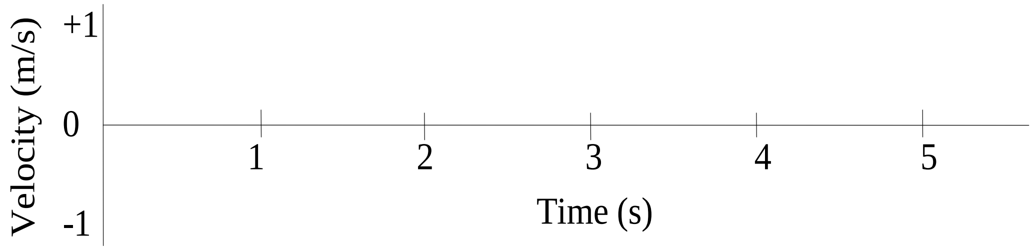
Activity #5: Making Velocity vs Time Graphs

Open the file *Velocity Graph.cmbl*. This will show a blank velocity vs time graph. Set the scale of the velocity axis from –1.0 to +1.0 m/s and the time axis from 0 to 5 s.

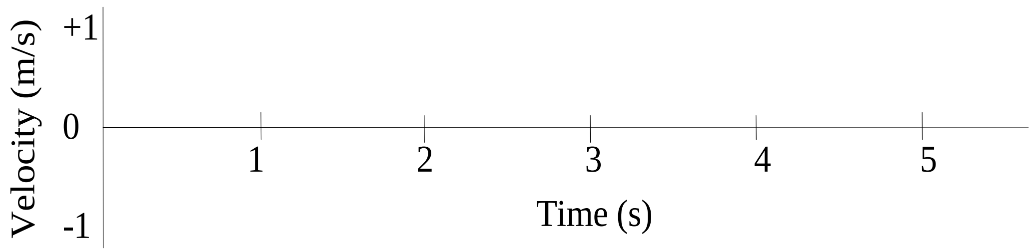
5a. Make a velocity graph by walking away from the sensor slowly and steadily. Try until you get a graph you are satisfied with and then sketch your result on the graph that follows. (We suggest you draw smooth patterns by ignoring smaller bumps that are mostly due to your steps, but ruler flat is impossible, realistically.)



5b. Make a velocity graph by walking away from the sensor steadily at a medium speed. Sketch your graph below.



5c. Make a velocity graph, walking towards the sensor slowly and steadily. Sketch your graph below.



5d. In what way do the velocity vs time graphs differ for walking away slowly from the sensor and walking away faster? Explain in terms of where the line was drawn, NOT in terms of what the velocity was.

5e. In what way do the velocity vs time graphs differ for motion away and motion towards the sensor? Explain in terms of where the line was drawn, NOT in terms of what the velocity was.

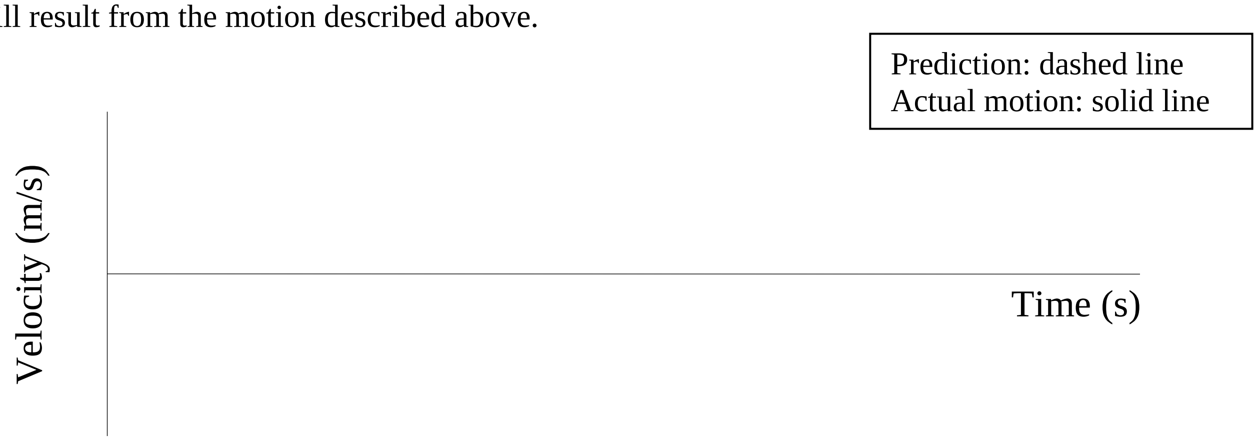
Predicting Velocity vs Time Graphs Based on Words

Suppose you were to undergo the following sequence of motions:

1. Walk away from the sensor slowly and steadily for 6s.
2. Stand still for 6s.
3. Walk toward the sensor steadily about twice as fast as before.

Activity #6: Predicting a Velocity vs Time Graph

6a. Adjust the length of the data collection to 15 s (using "Experiment"…"Data Collection"). Use a dashed line in the following graph to record your prediction of the shape of the velocity graph that will result from the motion described above.



6b. Now test your prediction by actually moving as described above. Repeat as necessary until you are satisfied that the graph matches the description in words. Now, on the graph above, draw what you saw on the monitor screen, with a solid line.

Did your prediction match your real motion? ______________
If not, what misunderstanding of the graph elements did you have?

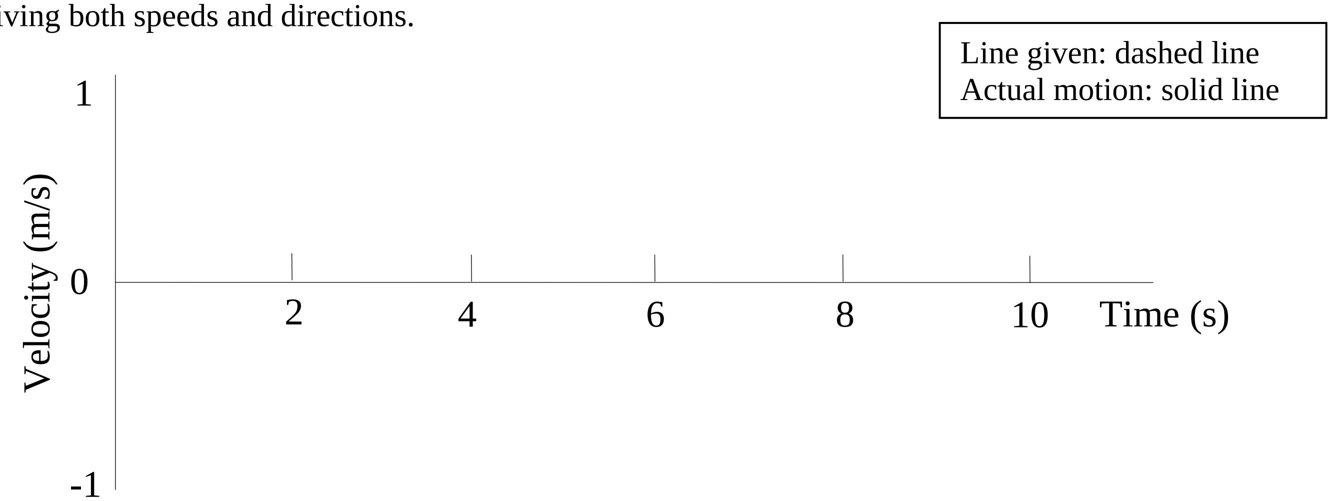
Velocity Graph Matching

In the next activity, you will try to move to match a velocity graph shown on the computer screen. This is often much harder than matching a position graph. In fact, some velocity graphs that can be invented cannot be matched!

To do this activity, open the file *Velocity Match.cmbl*. This overlay shows a velocity graph that you will try to match.

Activity #7: Matching a Velocity Graph

7a. Predict how you would have to move in order to match the *Velocity Match.cmbl* velocity graph, for the time period 0—2s, 2—4s, 4—7s and 7—10s. Write your prediction by each line segment, giving both speeds and directions.



7b. Now try to move in such a way that you can reproduce the graph shown. You may have to practice a number of times to get the movements right. Here, it really helps if you turn the monitor so that you can see it when you are moving. You and each person in your group should take a turn doing this. Draw in your group's best match on the graph with a solid line.

7c. Does your motion agree with your prediction? YES NO

7d. Is it possible for a moving object to produce an absolutely vertical line on a velocity-time graph? Explain. YES NO

7e. If you start your movement at 0.5 m away from the motion detector, did you end up walking too close to the motion detector on your return trip? YES NO

7f. Why did this happen (as in 7e), or why would this have happened?
(Hint: Compare how far you moved between "away/return".)

7f. How did/would you solve the problem?

7h. Does a velocity graph tell you where to start? YES NO
Explain.