SESSION ONE: DESCRIBING MOTION WITH WORDS AND GRAPHS

Distance vs. Time Graphs of Your Motion
In this session you will examine two different ways that the motion of an object can be represented graphically: first you will use a motion detector to create distance (position) vs. time graphs of the motion of your own body and then you will create velocity vs. time graphs.

Figure 1: Walking in front of a motion detector attached to a Computer-based Laboratory (or CBL) system.

The purpose of the first activity in this session is to learn how to relate graphs of distance as a function of time to the motions they represent.

How does a distance vs. time graph look when you move slowly? Quickly? What happens when you move toward the motion detector? Away? After completing the next few activities, you should be able to look at a distance vs. time graph and describe the motion of an object. You should also be able to to look at the motion of an object and sketch a graph representing that motion.

Note:
•"Distance" means "distance from the motion detector."
• The motion detector is located at the origin of each graph.

To do the activity and those that follow you should double check to see that: (1) a LabPro is connected to the computer, is turned on and has a motion detector plugged
in, and (2) that the Logger Pro program on your computer has been opened.

✍**Activity 3-1: Making Distance vs. Time Graphs**
 Make distance-time graphs for different walking speeds and directions by clicking on the start button at the bottom of the screen and walking in front of the motion detector at distances that are no closer than 0.5 m. Try the following motions and sketch the graph you observe in each case:
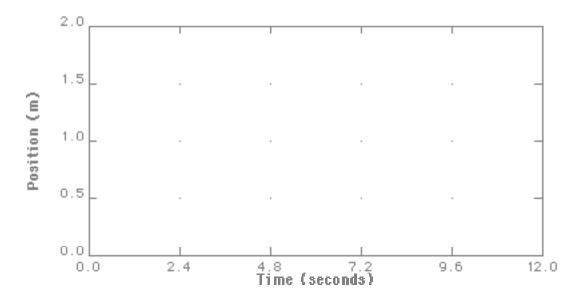
(a) Start at 0.3 m walk away from the origin (i.e., the detector) *slowly and steadily*.

(b) Walk away from the origin *medium fast and steadily*.

(c) Walk toward the detector (origin) *slowly and steadily*. Sketch the graph.

(d) Describe the difference between the graph you made by walking away slowly and the one made by walking away more quickly.

(e) Describe the difference between the graph made by walking toward and the one made walking away from the motion detector.

Note: It is common to refer to the distance of an object from some origin as the *position* of the object. Since the motion detector is at the origin of the co-ordinate system, it is better to refer to the graphs you have made as *position vs. time* graphs.

Predicting the Graph of a Motion Described in Words
A good way to double check that you understand how to interpret position vs. time graphs is to predict the shape of a graph that would result if a motion that can be described in words and then carry out the motion.

✎**Activity 3-2: Predicting a Position vs. Time Graph**
(a) Suppose your were to start 1.0 m in front of the detector and walk away slowly and steadily for 4 seconds, stops for 4 seconds, and then walk toward the detector quickly. Sketch your prediction on the axes below using a *dashed* line.

(b)Test your prediction by opening the RTP experiment file **L1A1-1 (Away and Back)**. (Select **Open** on the File menu, and double click with the mouse pointing to this experiment.) Move in the way described and use the graph above to sketch the actual trace of your actual motion *with a solid line*.
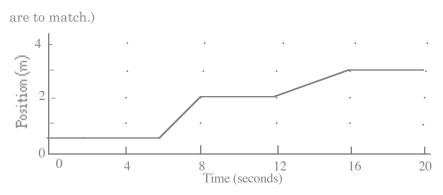
(c) Is your prediction the same as the final result? If not, describe how you would move to make a graph that looks like your *prediction*.

Matching Position vs. Time Graphs
Can you turn the activity you just did inside out? We'd like you to be able to look at a graph and then be able to describe the motion it depicts in words. The real test is to be able to reproduce the motion correctly.

✍**Activity 3-3: Matching Position vs. Time Graphs**
(a) To do the first matching activity you should Open the experiment file called **L1A1-2 (Position Match).** A position graph like that shown on the following graph should appear on the screen. (This graph is stored in the background as data B so you will be able to move in front of the detector and see your graph (as data A) traced out on top of the trace you
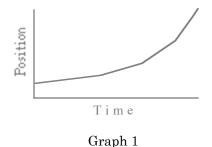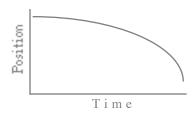
are to match.)

(b) Describe in your own words how you plan to move in order to match this graph.

(c) Move to match the **Position Match** graph on the computer screen. You may try a number of times. It helps to work in a team. Get the times right. Get the positions right. Do this for yourself. (Each person in your group should do his or her own match.) *You will not learn very much by just watching!*

(d) What was the difference in the way you moved to produce the two differently sloped parts of the graph you just matched?

(e) Make curved position vs. time graphs like those shown below.
Note: Before trying to reproduce the shapes shown below, get rid of the graph you just matched by choosing "Hide Data B" from the data menu in the Motion software.

Graph 1

Graph 2

(f) Describe how you must move to produce a position vs. time graph with each of the shapes shown.

Graph 1 answer:

Graph 2 answer:

(g) What is the general difference between motions which result in a straight line position vs. time graph and those that result in a curved-line position vs. time graph?

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30 min

Velocity vs. Time Graphs of Your Motion

You have already plotted your position as a function of time. Another way to represent your motion during an interval of time is with a graph which describes how fast and in what direction you are moving from moment to moment. How fast you move is known as your speed. It is the rate of change of position with respect to time. *Velocity* is a quantity which takes into account your *speed* and the *direction* you are moving. Thus, when you examine the motion of an object moving along a line, its velocity can be positive or negative meaning the velocity is in the positive or negative direction.

Graphs of velocity over time are more challenging to create and interpret than those for position. A good way to learn to interpret them is to create and examine velocity vs. time graphs of your own body motions, as you will do in the next few activities. You will need the following:

- *Logger Pro* software
- Motion detector
- *LabPro* Interface
- Number line on floor in metres (optional)

To do the next few activities you should Open the motion software and set it to graph velocity. To do this you can double click anywhere on the position graph to display a dialogue box. Move the
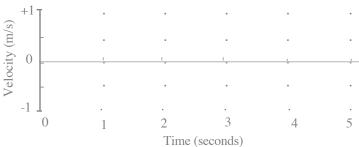
mouse pointer to the *Position* label, hold down the button and se-
lect *Velocity*. Set the *Velocity* axis from *–1.0 to +1.0 m/s*. Also
change the *Time* axis to read *0 to 5 s*.

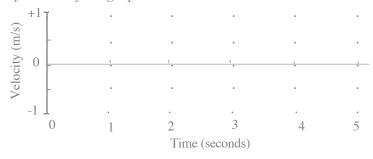## ✍️Activity 3-4: Making Velocity vs. Time Graphs

Note: To change the scale of your graph so the trace fills the screen better, double click on the original graph and use the dialogue box that pops up to choose a different maximum and minimum velocity

(a) Make a velocity graph by walking *away* from the detector *slowly and steadily*. Try again until you get a graph you're 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.).

(b) Make a velocity graph, walking *away* from the detector *steadily* at a *medium speed*. Sketch your graph below.

(c) Make a velocity graph, walking *toward* the detector slowly *and steadily*. Sketch your graph below.

(d) What is the most important difference between the graph made by *slowly* walking away from the detector and the one made by walking away *more quickly*?
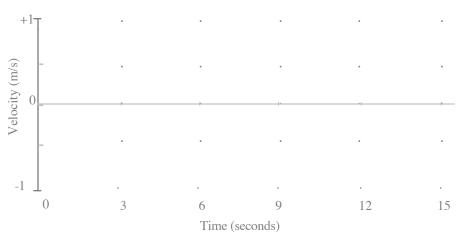
(e) How are the velocity vs. time graphs different for motion *away* and motion *toward* the detector?

Predicting Velocity vs. Time Graphs Based on Words
Suppose you were to undergo the following sequence of motions:
1. walk away from the detector slowly and steadily for 6 seconds

2. stand still for 6 seconds

3. walk toward the detector steadily about twice as fast as before
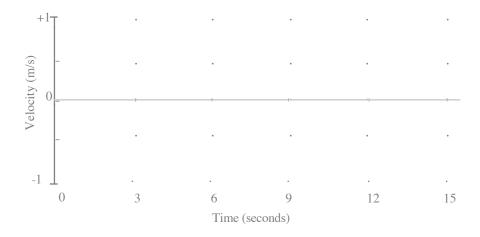

✎ **Activity 3-5: Predicting a Velocity vs. Time Graph**
(a) Use a *dashed line* in the graph that follows to record your *prediction*
of the shape of the velocity graph that will result from the motion de-
scribed above.

(b) Compare predictions with your partner(s) and see if you can all
agree. Use a solid line to sketch your group prediction in the graph
above.

(c) Adjust the time scale to 15 s in the Motion Software and then test
your prediction. Repeat your motion until you are confident that it
matches the description in words and then draw the actual graph on the
axes below. Be sure the 6-second stop shows clearly.

Final Result

+1

-1

Velocity (m/s)

0

0   3   6   9   12   15

Time (seconds)

1. (d) Did your prediction match your real motion? If not what misunderstanding of what the elements of the graph represent did you have?

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Comments about Velocity Graphs:
(1) Velocity implies both speed and *direction*. How fast you move is your speed, the rate of change of position with respect to time. As you have seen, for motion along a line (e.g., the positive x-axis) the sign (+ or -) of the velocity indicates the direction. If you move away from the detector (origin), your velocity is positive, and if you move toward the detector, your velocity is negative.

(2) The faster you move *away* from the origin, the larger positive number your velocity is. The faster you move *toward* the origin, the "larger" negative number your velocity is. That is -4 m/s is twice as fast as -2 m/s and both motions are toward the origin.

Velocity Vectors:
These two ideas of speed and direction can be combined and represented by *vectors*.
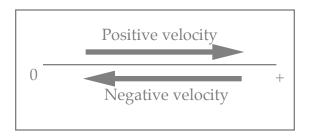
A velocity vector is represented by an arrow pointing in the direction of motion. The length of the arrow is drawn proportional to the speed; the longer the arrow, the larger the speed. If you are moving toward the right, your velocity vector can be represented by the arrow shown below.
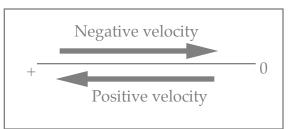
If you were moving twice as fast toward the right, the arrow representing your velocity vector would look like:

while moving twice as fast toward the left would be represented by the following arrow:

What is the relationship between a one-dimensional velocity vector and the *sign* of velocity? This depends on the way you choose to set the positive x-axis.

In both diagrams the top vectors represent velocity toward the right. In the left diagram, the x-axis has been drawn so that the positive x-direction is toward the right. Thus the top arrow represents *positive* velocity. However, in the right diagram, the positive x-direction is toward the left. Thus the top arrow represents *negative* velocity. Likewise, in both diagrams the bottom arrows represent velocity toward the left. In the left diagram this is *negative* velocity, and in the right diagram it is *positive* velocity.
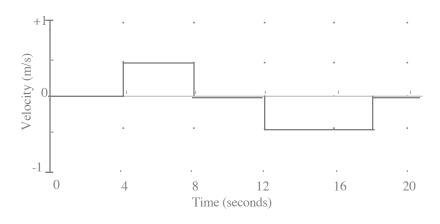

✍️**Activity 3-6: Sketching Velocity Vectors**
 Sketch below velocity vectors representing the three parts of the motion described in the prediction you made in Activity 3-5.

(a) Walking slowly away from the detector:

(b) Standing still:

(c) Walking rapidly toward the detector:
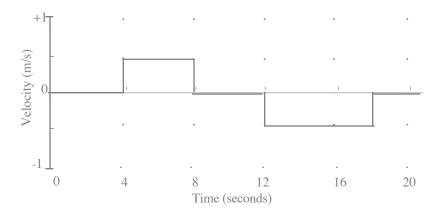

Velocity Graph Matching
In the next activity, you will try to move to match a velocity graph shown on the computer screen. This is often much harder than matching a position graph as you did in the previous investigation. Most people find it quite a challenge at first to move so as to

match a velocity graph. In fact, some velocity graphs that can be invented cannot be matched! To do this activity
pull down the File Menu and select **Open.** Then double click on **L1A2-2 (Velocity Match)**. The following velocity graph should appear on the screen.

✎Activity 3-7: Matching a Velocity Graph

(a) Describe how you think you will have to move in order to match the given velocity graph.

(b) 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. Work as a team and plan your movements. Get the times right. Get the velocities right. You and each person in your group should take a turn. Then draw in your group's best match on the axes that follow.

(c) Describe how you moved to match each part of the graph.

(d) Is it possible for an object to move so that it produces an absolutely vertical line on a velocity time graph? Explain.

(e) Did you run into the motion detector on your return trip? If so, why did this happen? How did you solve the problem? Does a velocity graph tell you where to start? Explain.

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35 min

Relating Position and Velocity Graphs

You have looked at position and velocity vs. time graphs separately. Since position vs. time and velocity vs. time graphs are different ways to represent the same motion, it ought to be possible to figure out the velocity at which someone is moving by examining her/his position vs. time graph. Conversely, you ought to be able to figure out how far someone has travelled (change in position) from a velocity vs. time graph.

To explore how position vs. time and velocity vs. time graphs are related, you will need the following:

- *Logger Pro* software
- Motion detector
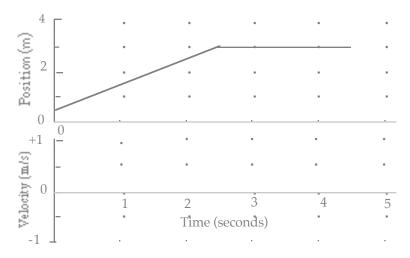- LabPro Interface
- Number line on floor in metres (optional)

To complete the next Activity, you'll need to set up the Motion Software to display both position vs. time and velocity vs. time simultaneously. To do this:

1. Clear data from any previous graphs
2. Pull down the Display Menu and select *Two Graphs*.

3. Set the top graph to display *Position* from *0 to 4* m for 5 s.

4. Set the bottom graph to display *Velocity* from *-1 to 1 m/s* for 5 s.

✎**Activity 3-8: Predicting Velocity Graphs from Position Graphs**

(a) Carefully study the position graph shown below and predict the velocity vs. time graph that would result from the motion. Using a *dashed line*, sketch your *prediction* of the corresponding velocity vs. time graph on the velocity axes.

(b) After each person in your group has sketched a prediction, test your prediction by matching the position vs. time graph shown.
When you have made a good duplicate of the position graph, sketch your actual graph over the existing position vs. time graph.

(c) Use a *solid line* to draw the actual velocity graph on the same graph with your prediction. (Do not erase your prediction).

(d) How would the position graph be different if you moved faster? Slower?

(e) How would the velocity graph be different if you moved faster? Slower?

Estimating and Calculating Velocity

In this activity, you will estimate an average velocity from the velocity graph you created in the previous Activity and then calculate an average velocity using your position graph.

✍️Activity 3-9: Average Velocity Calculations

(a) Find your average velocity from your velocity graph in the previous activity. Select **Examine** in the Analyze menu, read a number of values (say ten) *from the portion of your velocity graph where your velocity is relatively constant*, and use them to calculate the average (mean) velocity.

Velocity values   ____ ____ ____ ____ ____

from graph (m/s)____ ____ ____ ____ ____

Average value of the velocity: _____m/s

Note: Average velocity during a particular time interval can also be calculated as the change in position divided by the change in time. (The change in position is often called the *displacement.*) By definition, this is also the *slope* of the position vs. time graph for that time period. As you have observed, the faster you move, the more inclined is your position vs. time graph. The *slope* of a position vs. time graph is a quantitative measure of this incline, and therefore it tells you the velocity of the object.

(b) Use the method just described in the note to calculate your average velocity from the slope of your position graph in Activity 3-7. Use **Examine** (under the Analyze menu) to read the position and time co-ordinates for two typical points *while you were moving*. (For a more accurate answer, use two points as far apart as possible but still typical of the motion, and within the time interval over which you took velocity readings in Activity 3-8.)

	Position (m)	Time (sec)
Point 1		
Point 2		

(c) Calculate the change in position (displacement) between points 1 and 2. Also calculate the corresponding change in time (time interval). Divide the change in position by the change in time to calculate the *average* velocity. Summarize the results of your calculations below.
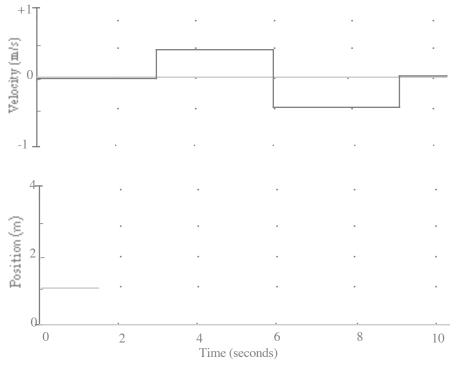
Change in position (m)	
Time interval (sec)	

Average velocity (m/s)	

(d) Is the average velocity positive or negative? Is this what you expected?

(e) Does the average velocity you just calculated from the position graph agree with the average velocity you estimated from the velocity graph? Do you expect them to agree? How would you account for any differences?

Predicting Position Graphs from Velocity Graphs
The final challenge is to be able to produce position vs. time graphs from velocity graphs. In order to do this successfully, you need to know the position of the person or object of interest at least one of the times.

✍**Activity 3-10: Finding Position from a Velocity Graph**
(a) Carefully study the velocity graph that follows. Using a *dashed line*, sketch your *prediction* of the corresponding position graph on the bottom set of axes. (Assume that you started at the 1-metre mark.)

(b) After each person has sketched a prediction, do your group's best to duplicate the top (velocity vs. time) graph by walking. (Reset the **Time** axis to 0 to 10 seconds before you start.) When you have made a good duplicate of the velocity vs. time graph, draw your actual result over the existing velocity vs. time graph.

(c) Use a *solid line* to draw the actual position vs. time graph on the same axes with your prediction. *Do not erase your prediction.*

(d) How can you tell from a *velocity* vs. time graph that the moving object has changed direction?

(e) What is the velocity at the moment the direction changes?

(f) Is it possible to actually move your body (or an object) to make verti-cal lines on a position vs. time graph? Why or why not? What would the velocity be for a vertical section of a position vs. time graph?

(g) How can you tell from a position vs. time graph that your motion is steady (motion at a constant velocity)?

(h) How can you tell from a velocity vs. time graph that your motion is steady (constant velocity)?