EXPLORATIONS

Name ____________________________

Date ____________________________

Activity 12

A Move in the Right Direction

Usually when you make a graph, you are given a table of data in the form of ordered pairs (x,y). You then plot the points representing those ordered pairs and analyze the graph for any patterns that can be described mathematically (such as $y = x + 5$). In some cases you may have to collect the data first, so the process has four steps: collect the data, organize it into ordered pairs, graph it, and analyze it. In this activity, you will physically provide the data yourself and you will use equipment that will simultaneously graph the data as you provide it.

The Problem

In this activity, you will use your graphing calculator in conjunction with a motion sensor and a device known as a CBL™ (Calculator-Based Laboratory™). The CBL allows you to collect data using a variety of probes or sensors. The collected data is stored in lists in the graphing calculator for further analysis.

You will need to have a motion sensor and a CBL™ for each group of three or more students. The transparency master, Guidelines for Working with the CBL and Motion Sensor, provided in the ***Appendix****, can be used in discussing important points about using the equipment before students begin the experiment.*

You will work through several experiments requiring you to produce and study graphs that display the *distance* of a moving object from a particular point with respect to *time*. Each experiment will involve a person walking toward and/or away from the motion detector in an attempt to produce a graph like one provided in the experiment.

Your teacher will discuss several important points concerning correct set-up and usage of the CBL and motion sensor before you begin conducting any experiments.

It would be helpful for you to demonstrate the physical connections needed for CBL/calculator/motion sensor set up. Two steps are needed to properly connect these three devices:

(1) Connect the CBL to the calculator with the black linking cable inserted firmly into the I/O ports located along the bottom edge of each of the units.

(2) Connect the motion sensor to the CBL usingthe SONIC port on its left edge.

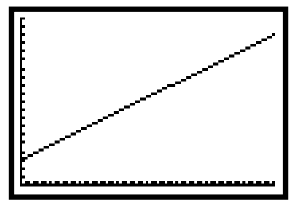
Each calculator used in conjunction with a CBL and motion sensor must hold the ***HIKER*** *program in memory. This program is available in the publication* ***CBL SYSTEM Experiment Workbook*** *that accompanies each CBL or in the CBL folder for the TI-Graph Link™ software. If you have access to a TI-Graph Link, download this program from disk to the calculators. Without the TI-Graph Link, the program will have to be entered by hand into one calculator and transferred to the remaining ones using the* ***LINK*** *feature. A printed copy of the* ***HIKER*** *program is provided in the* ***Appendix****.*

Once your equipment has been set up and you have discussed the points concerning operation of the equipment, you are ready to begin the experiment. Make certain your motion sensor is connected to the CBL through the SONIC port and that the CBL is linked to the calculator using the black linking cable.

One group member will serve as walker and another will operate the calculator and let the walker know when an experiment should start. Group members will change tasks after each experiment, giving each a chance to *move in the right direction*.

Experiment 1

In this experiment, the walker should attempt to walk a path that makes the calculator show a graph very similar to the one at the right.



We will "walk" through Experiment 1 as an example of the reasoning you might use in the remaining experiments.

You first need to look at the calculator display and determine key information given to you by the graph. Start at the point farthest to the left where the *x*-coordinate is 0. The *x*-axis represents time, so when the experiment begins (at *time* = 0), the graph shows a *y*-coordinate with some positive value. The *y*-axis represents distance from the sensor. The *y*-scale will be set to 1.0 by the program you will be using in this activity.

✐ Go to the **Questions** section and answer #1 and #2.

The graph also tells us something about the *speed* of the walker. You may have found the slope of a line before using two points on the line (x_1, y_1) and (x_2, y_2) and calculating the slope ratio as

$$\text{slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)} = \frac{\text{rise}}{\text{run}}.$$

Since this graph shows a relationship between distance (in feet) and time (in seconds), the

$$\frac{\text{rise}}{\text{run}} \text{ provides information on } \frac{\text{(change in distance)}}{\text{(change in time)}}$$

in terms of feet/second. This quotient represents the walker's speed. You can compute a rough estimate of the walker's speed by using the coordinates of the beginning point and the coordinates of one other point on the graph. It is difficult to read the *x*-axis with its small scale but you know the *x*-coordinate of the *last* point plotted is 6 since the program stops collecting data after a time of 6 seconds.

✐ Go to the **Questions** section and answer #3 and #4.

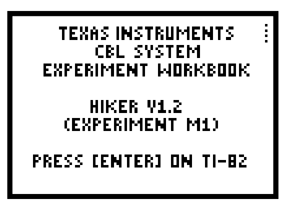
Using the Calculator and CBL

As you conduct your experiment, follow this **Four-Step Data Collection Procedure**:

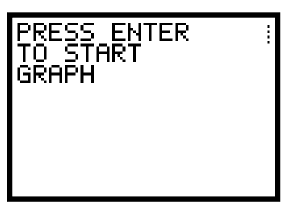
1. Have the walker get into the starting position your group suggested based on your analysis of the graph.

2. Have the person in charge of the calculator turn it on. Then press [PRGM] and use [▼] to highlight the line showing the **HIKER** program name. Press [ENTER] [ENTER].

   The calculator display should look something like the one shown at the right.



3. Follow the directions shown on the calculator screen. If everything is connected properly, you should get to a screen like the one at the right after pressing [ENTER] three more times.

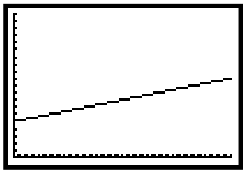
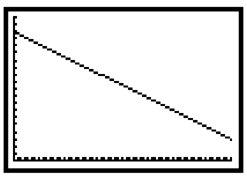
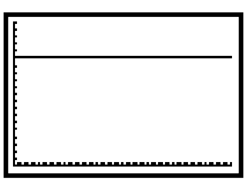


4. When the walker is ready, the calculator person should say "start" and press [ENTER] at the same time (and not before) the walker begins moving at the pace determined by the group from their analysis of the graph. The walker should continue for at least six seconds. Once the motion sensor stops collecting data (it stops clicking), the calculator person should say "stop."

It is not crucial that students walk exactly the same graph. What is important is that they learn through experience that walking faster produces steeper graphs, walking away or toward the sensor produces different slopes (left to right or right to left), and that the beginning point of a walk is associated with the "y-intercept" of the graph. The experiments will help the students' understanding of the important information that graphs can provide. In another, more physical sense, students get to "feel" what it is like to be a line or curve.

Your group should examine the graph produced and compare it to the one provided. If the graph produced from your walker's movements does not look fairly close to the one provided, repeat the **Four-Step Data Collection Procedure** until you are satisfied with the results.

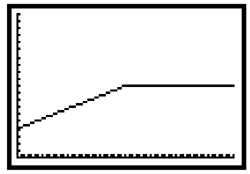
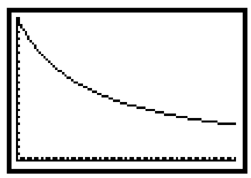
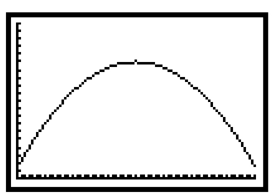
Switch roles and produce graphs that look like each of those in the experiments that follow. For each experiment, first develop and record a *walking strategy* based on your reading of the graphs shown and then carry out the **Four-Step Data Collection Procedure**.

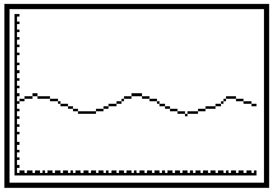
Experiment	Graph to Walk	Your Walking Strategy
2		
3		
4		

Begin about 5 feet away from the sensor and walk at a slow but steady pace away from the sensor.

Begin about 17 feet away from the sensor and walk at a moderate but steady pace toward the sensor.

Begin about 15 feet away from the sensor and stand still for 6 seconds.

	Experiment	Graph to Walk	Your Walking Strategy
Begin about 4 feet away from the sensor, walk at a moderate but steady pace away from the sensor for about 3 seconds. Then stop and hold position for the remainder of the experiment.	**5**		
Begin about 20 feet away from the sensor. Start walking at a brisk but decreasing pace toward the sensor slowing to a point of a near standstill by the end of the experiment.	**6**		
Start about 2 feet from the sensor and walk away at a brisk but decreasing pace. Slow to a point of reversing direction after about 3 seconds. Walk toward the sensor at an increasing pace for the remaining time. What is interesting here is that many students initially attempt to walk the curve; they walk a curved path in front of the sensor. This experiment is a great way to help them focus on what the graph is telling *them rather than* showing *them.*	**7**		

Experiment	Graph to Walk	Your Walking Strategy
8		
9	Produce a graph for others to walk.	

Begin about 9 feet from the sensor. Step away and then toward the sensor for the entire experiment. This provides a nice connection to simple harmonic motion.

Questions

At time zero, distance is about 3 feet.

1. Estimate the y-coordinate associated with $x = 0$. In other words, determine approximately how far the walker is from the motion sensor at the start of the experiment.

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2. A few seconds into the experiment, is the walker closer or farther away from the sensor? Explain your reasoning.

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Return to page 114.

Approximating the last point as (6, 17) and the first point as (0, 3), the estimated speed of the walker (slope of the line) is:

$$\frac{17-3}{6-0} = \frac{14}{6} \approx 2.3 \ {}^{\text{ft}}\!/_{\text{sec}}.$$

This means the walker is moving at about 2.3 feet/second away from the sensor.

3. Estimate the y-coordinate of this last data point and use the coordinates of the first and last points on the graph to estimate the slope of the line. The slope you compute will provide an estimate of the speed of the walker in Experiment 1.

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A possible walking strategy for Experiment 1:

Start approximately 3 to 4 feet in front of the sensor and walk at a moderate but steady pace away from the sensor.

4. Now, with all of the information you have collected from the graph of Experiment 1, write down a group strategy for "walking the line."

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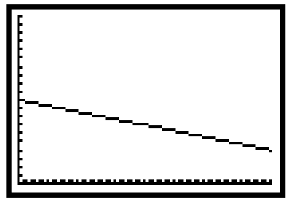
*Return to page 115, **Using the Calculator and CBL**.*

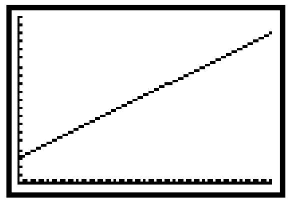
Problems for Additional Exploration

1. The graphs shown at the right represent two different walkers, A and B, moving in front of the motion sensor.

Walker A



Walker B



a. Which walker started his or her walk closest to the sensor? Explain.

Walker B started closer to the sensor as shown by the smaller y-intercept on the graph.

b. Which walker moved at a faster rate of speed? Explain.

Walker B walked at a faster rate of speed as shown by the steeper graph.

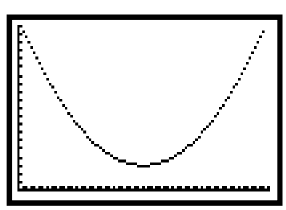
c. Which walker moved toward the sensor? Explain.

Walker A moved toward the sensor as shown by the slope of the graph dropping from left to right.

2. Describe a walking strategy that could produce a graph similar to the ones shown at the right.

Graph A:

Graph A

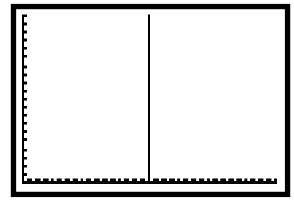


Start approximately 20 feet from the sensor walking toward the sensor fairly quickly but slowing the pace to reverse direction after about 3 seconds. Walk at an increasingly faster pace away from the sensor for the next 3 seconds.

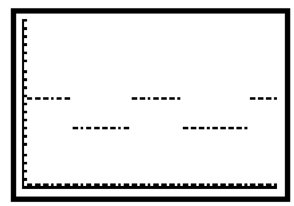
This graph is impossible to walk because it indicates that at a time of 3 seconds, the walker would have to be at all locations in front of the sensor at the same time. Note that all walkable graphs are functions since a body can be at only one place at any given time. This graph is not a function.

Graph B:

Graph B



3. The graph at the right was produced using the motion sensor. How do you think this might have been accomplished?



The graph was formed by pointing the sensor at the ceiling and then periodically inserting and removing a book between the sensor and the ceiling. It is also possible to point the sensor at a wall and then have a student move in and out of the path detected by the sensor.

*(**Hint**: the experiment did not involve a single person walking.)*

4. Describe how you used information in the graphs to determine how to *walk the graph*. For example, how you knew where to start the walk, when to walk faster or slower, when to move toward or away from the sensor, and when to move at a steady or varying pace.