



Math and Science in Motion: Activities for Middle School

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Preface

This workbook is intended to provide middle school students with an interactive and visual means of exploring math and science concepts. The activities are written to use the Texas Instruments TI-82 or TI-83 graphing calculator in conjunction with the Calculator-Based Ranger™ (CBR™). The CBR collects motion data that is retrieved and analyzed on the calculator. The keystrokes outlined in the activity procedures are common to the TI-82 and TI-83, and you should notice no difference in their functionality.

The activities in this book cover a wide range of topics. Some require mathematical computation while others are purely qualitative in nature. Such variety makes the investigations accessible to students of many levels and capacities.

The activities are organized in worksheet format with background information and step-by-step keystrokes. Space is provided for students to record data and calculations, and questions are included to extend the lesson. Answers to the activity questions and helpful notes are supplied to teachers in Appendix A.

On a final note, we want to express our gratitude to all those people who were instrumental in the production of this workbook. Jim Stephens and Jan Mosteller of Brunswick School; Paul Carrillo, John Good, Pat Hatcher, and Julie Hewlett of Texas Instruments tested the activities in this workbook and provided many helpful comments and suggestions. Thanks also to Jeanie Anirudhan, Susan Gullord, Nelah McComsey, and Dianna Tidwell of Texas Instruments who supervised the production of this workbook and helped with the editing and formatting process.

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— *Bill Bower*

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The authors are all active in professional development programs for middle and secondary math and science teachers and instruct summer workshops through the Teachers Teaching with Technology Program. Together, they have collaborated to write *Real World Math with the CBL System* and *Discovering Math on the TI-92*, both Texas Instruments publications.

ACTIVITY 5

Shape Up!



The direction you move, the speed you travel, and the rate at which you change your direction and speed all have an effect on the shape of a Distance-Time plot. Would it be possible to use these factors to plot specific shapes on the calculator while moving in front of the CBR? Is it possible to plot any shape you desire on the screen? What determines if a shape can be plotted by your motion in front of the CBR?

Objectives

In this activity you will:

- ◆ Discover what type of shapes can be plotted as a result of your motion in front of the CBR.
- ◆ Observe which shapes can and cannot be made with a Distance-Time plot.
- ◆ Determine a rule for which shapes can be made by walking in front of the CBR.

You'll Need

- ◆ CBR unit
- ◆ TI-82 or TI-83 and calculator-to-CBR cable

CBR Setup

1. Connect the CBR to the calculator using the link cable.
2. Turn on your calculator. If you have not already loaded the **RANGER** program into your calculator, follow these steps:
 - a. Press $\boxed{2\text{nd}}$ $\boxed{[\text{LINK}]}$ $\boxed{\blacktriangleright}$ $\boxed{[\text{ENTER}]}$. The calculator displays **Waiting ...**
 - b. Press the $\boxed{82/83}$ transfer button on the CBR.
3. Run the **RANGER** program on your calculator:
 - a. Press $\boxed{[\text{PRGM}]}$.
 - b. Choose **RANGER**.
 - c. Press $\boxed{[\text{ENTER}]}$.

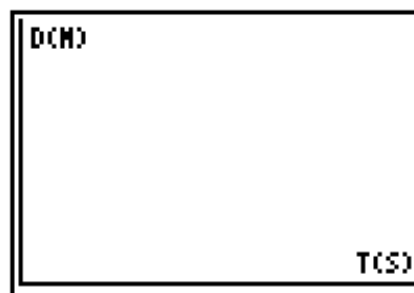
4. From the **MAIN MENU**, select **2: SET DEFAULTS**.
5. With the selector arrow (▶) at **START NOW**, press **[ENTER]**.

Collecting the Data and Looking at the Results

In this activity you will move in front of the CBR applying what you know about Distance-Time plots to create different shapes. You must take care only to move back and forth in front of the CBR and never to the side. This ensures that the CBR will record your motion.

1. Describe how you would have to move in front of the CBR in order to create a plot that resembles a mountain with a plateau on top.

2. Create the plot described above by walking in front of the CBR as described in your answer to number 1. Press **[ENTER]** to start. As you walk, you should try to match the plot. If you are satisfied with the resulting plot, sketch it on the axes to the right. If not, press **[ENTER]**, choose **3: REPEAT SAMPLE**, and then repeat the trial.

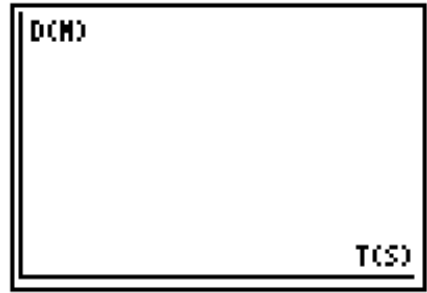


3. Did the plot in number 2 produce the desired shape? Describe any problems that you encountered while trying to make the plot and whether or not the problems could be eliminated in another trial.

4. Describe the way you would move to create a mountain with a sharp peak. How could your motion make the sides of the mountain steeper?

5. Press **[ENTER]**, choose **3: REPEAT SAMPLE**. Using the method described in number 4, walk in front of the CBR and create a mountain range consisting of at least two mountains, both with sharp peaks of equal heights. Make the sides of the second mountain steeper than those of the first.

Press **ENTER** when you are ready to begin. If you are satisfied with the resulting plot, sketch it on the axes to the right. If not, press **ENTER**, choose **3: REPEAT SAMPLE**, and then repeat the trial.

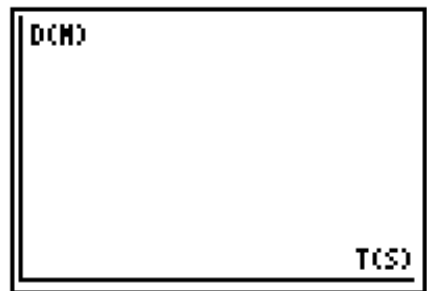


6. How would your motion change if you wanted the second peak to be only half as high as the first peak?

7. Suppose you wanted to make a plot of the uppercase letter **V**. Describe how you would walk to create this plot.

8. Press **ENTER** and choose **3: REPEAT SAMPLE**. Walk in the way you described above to create the uppercase letter **V**.

Press **ENTER** when you are ready to begin. If you are satisfied with the resulting plot, sketch it on the axes to the right. If not, press **ENTER**, choose **3: REPEAT SAMPLE**, and then repeat the trial.

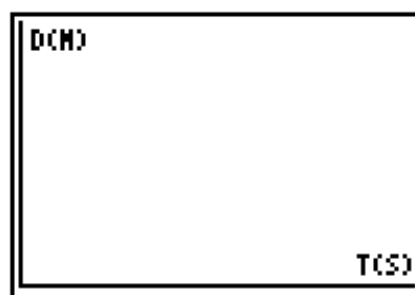


9. What change in your motion would result in a **U** rather than a **V**?

10. Suppose you wanted to make the lowercase letter **m**. Describe how you would walk to create this plot. Be sure to discuss the speed as well as the direction of your motion.

11. Press **ENTER** and choose **3: REPEAT SAMPLE**. Walk in the way you described above to create the lowercase letter **m**.

Press **ENTER** when you are ready to begin. If you are satisfied with the resulting plot, sketch it on the axes to the right. If not, press **ENTER**, choose **3: REPEAT SAMPLE**, and then repeat the trial.



12. How could you change your motion in number 11 to produce a **W** rather than an **M**?

Going Further

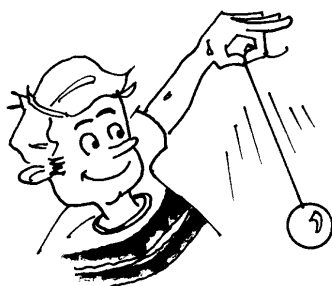
Answer these questions on a separate sheet of paper. Show all work.

- Some of the figures you plotted had sharp corners and others had rounded edges. What was the key factor in your movement that determined which type was plotted? Explain why this factor affects the plot in this way. (Be sure to use the word “rate” in your answer.)
- Would it be possible to move in such a way as to create a plot of a circle? Explain whether or not this can be done. If you feel that you can make a circle, press **ENTER** on your calculator, choose **3: REPEAT SAMPLE**, press **ENTER**, and attempt to do so. Discuss what happened and why.
- List all uppercase and lowercase letters that you believe you could make a plot of by moving in front of the CBR.
- List five letters that you would not be able to make by moving in front of the CBR. What is it about these letters that makes them impossible to plot?
- What was the determining factor in both the shapes and the letters that made something impossible to plot by moving in front of the CBR? (Be sure to use the word “time” when discussing the motion involved.)

Choose other letters or shapes that can be made by walking in front of the CBR. Write down directions for creating each plot and then have a classmate try to guess the shape after reading your directions. Finally, allow your classmate to check the answer by walking in front of the CBR.

ACTIVITY 10

Swing Thing



When you swing back and forth on a playground swing, you're modeling the motion of a simple pendulum. What affects the way a pendulum swings? Its length? How far it is pulled back before you release it? The weight of the object hanging from it? When the important characteristics of a pendulum are identified, you can use math to make predictions about its motion.

Objectives

In this activity you will:

- ◆ Construct a *pendulum*.
- ◆ Create a motion plot for a swinging pendulum.
- ◆ Identify characteristics that effect a pendulum's motion.

You'll Need

- ◆ CBR unit
- ◆ TI-82 or TI-83 and calculator-to-CBR cable
- ◆ Meter stick
- ◆ String
- ◆ Scissors
- ◆ Empty aluminum can with pull-tab
- ◆ Funnel
- ◆ Sand

CBR Setup

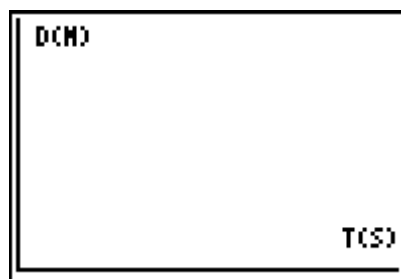
1. Connect the CBR to the calculator using the link cable.
2. Turn on your calculator. If you have not already loaded the **RANGER** program into your calculator, follow these steps:
 - a. Press $\boxed{2\text{nd}}$ $\boxed{[\text{LINK}]}$ $\boxed{\blacktriangleright}$ $\boxed{[\text{ENTER}]}$. The calculator displays **Waiting ...**
 - b. Press the $\boxed{82/83}$ transfer button on the CBR.
3. Run the **RANGER** program on your calculator:
 - a. Press $\boxed{[\text{PRGM}]}$.
 - b. Choose **RANGER**.
 - c. Press $\boxed{[\text{ENTER}]}$.
4. From the **MAIN MENU**, select **2: SET DEFAULTS**.
5. With the selector arrow (\blacktriangleright) at **START NOW**, press $\boxed{[\text{ENTER}]}$.

Collecting the Data

1. Tie one end of the string to an empty aluminum can. Measure 50 centimeters of the string and cut the string at this point.
2. Place the CBR on a table or desk. Position the pendulum about 1 meter from it. Be sure you are holding the string by its end.
3. Aim the sensor at the can. Pull the can back about 10 centimeters and release it so that it swings toward and away from the sensor. When you are ready to begin collecting data, press $\boxed{[\text{ENTER}]}$.

Your plot should show a smooth, wave-like plot.

4. If you are satisfied with your plot, sketch it at the right, and go on to the next section. If not, press $\boxed{[\text{ENTER}]}$, select **3: REPEAT SAMPLE** from the **PLOT MENU**, and try again.



Looking at the Results

1. A pendulum completes a cycle as it moves from one extreme position to the other and back again. How many complete cycles are displayed on calculator screen?

2. The time required for the pendulum to complete a cycle is called the *period*. To find your pendulum's period, use $\boxed{\blacktriangleright}$ and $\boxed{\blacktriangleleft}$ to trace to the first peak and record the time (x-value) below.

First Peak: _____ seconds

Trace to the second peak and record the x-value below.

Second Peak: _____ seconds

When you have finished tracing the data, press **[ENTER]**. From the **PLOT MENU**, select **5: QUIT**. Press **[CLEAR]**.

3. The period is the difference between the two time peaks. Find the period and record it below.

Period: _____ seconds

4. How do you think the period would be affected if a heavier can were used? Record your prediction below.

Insert the funnel into the can's opening. Add some sand to the can so that it is about half-filled. Repeat the experiment, exactly as described above with the heavier can. Record your results below.

First Peak: _____ seconds

Second Peak: _____ seconds

Period: _____ seconds

Are the periods significantly different for the light can and the heavy can? Does this result agree with your hypothesis?

5. How do you think the period would be affected if a shorter piece of string were used? Record your prediction below.

Measure 25 centimeters along the string that is already attached to the can and cut the string at this point. Repeat the experiment, exactly as described above with the shorter string. Record your results below:

First Peak: _____ seconds

Second Peak: _____ seconds

Period: _____ seconds

Are the periods significantly different for the longer string and the shorter string? Does the result agree with your hypothesis?

6. Complete the following statement based on your observations during this activity. (Use the words "increase," "decrease," or "remain the same.")

Changing the weight of the pendulum's hanging object causes its period to _____, and decreasing its length causes its period to _____.

Going Further

Answer these questions on a separate piece of paper. Show all work.

1. In the second part of this activity, the pendulum's length was divided in half, and this caused its period to change. Was the period divided in half also? What does this tell you about the relationship between pendulum length and period?

2. The *frequency* of a swinging pendulum tells how many cycles it completes per second. Frequency and period are related by this simple formula:

$$\text{Frequency} = 1 \div \text{Period}$$

Based on the data you collected, find the frequencies for the long-string pendulum and the short-string pendulum.

3. How would frequency be affected (increase, decrease, or remain the same) if the pendulum length increased? How would frequency change if a pendulum's period is tripled? Be specific.

Appendix A

Teacher Information

This section provides general information, practice data, and answers for the student activities.

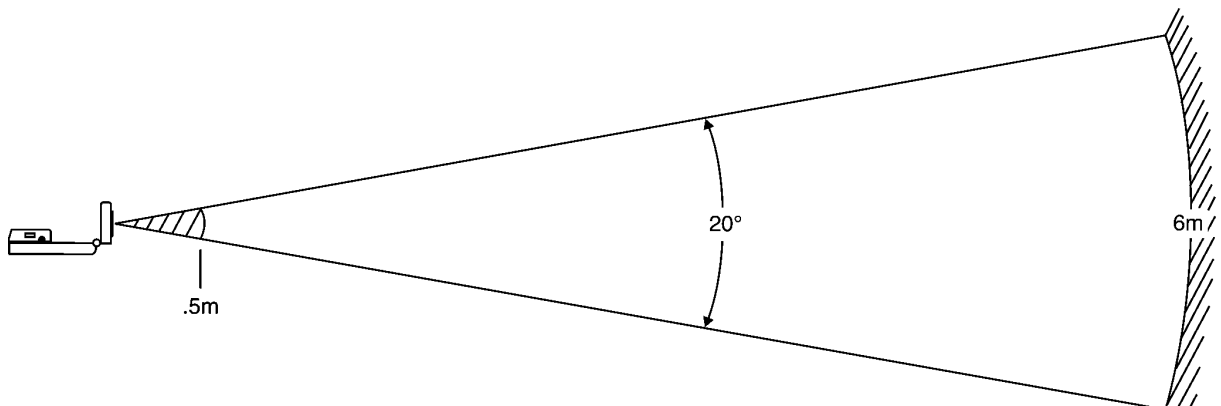
Activity Notes

- ◆ The CBR setup instructions are included in each activity.
- ◆ If you need additional information, refer to the *Getting Started with CBR* manual included with the CBR.
- ◆ Remind students that the CBR records motion in front of it, not to the side.
- ◆ Be sure that students stay within the range of the CBR (0.5 – 6 meters).
- ◆ Most students prefer to face the CBR when walking. This allows them to stay directly in front of the unit during data collection.

The Clear Zone

The path of the CBR beam is not a narrow, pencil-like beam, but fans out in all directions up to 10° in a cone-shaped beam.

To avoid interference from other objects in the vicinity, try to establish a clear zone in the path of the CBR beam. This helps ensure that objects other than the target are not recorded by the CBR. The CBR records the closest object in the clear zone.



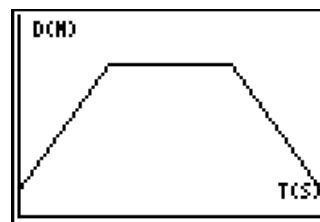
Activity 5 — Shape Up

Collecting the Data and Looking at the Results

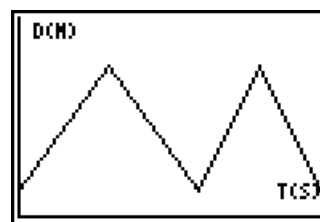
- ◆ Don't worry if the activity being performed ends before the CBR is finished collecting data. Simply stand still when you finish and ignore the resulting horizontal line in the answer.

You can practice this activity by using the sample screen shots provided. Remember, there will be differences between the plots from the data that students collect and the sample screens. In most cases, these will not be significant. As long as the general shape of the plot is preserved, the student plot will be acceptable.

1. The student would stand about 0.5 meters from the CBR. When data collection begins, the student would walk away from the CBR at a steady rate for 4-5 seconds, stop and remain in the same place for the next few seconds, and finally walk back to the original starting point at a steady rate.
2. The plot should resemble the one shown.

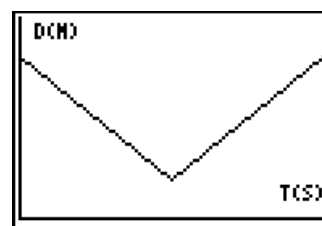


3. Answers will vary.
4. The walker would move at a fast rate away from the CBR for about 3 or 4 meters and then abruptly change directions and move back at the same rate to the original starting position. The faster the rate the student walks, the steeper the resulting plot will be.
5. The plot should resemble the one shown.



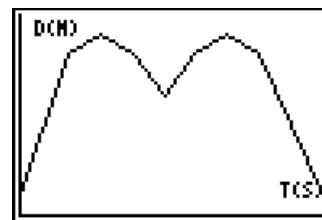
6. The walker would only move half of the distance that he or she had moved in making the first peak before changing directions.
7. To make the uppercase letter **V**, the walker should begin about 5 meters from the CBR and walk toward the CBR at a steady rate until they are about 1 meter from the CBR. At this point, they should abruptly change directions and return at the same rate to the original starting position.

8. The plot should resemble the one shown.



9. Instead of abruptly changing directions, the walker would slow to a stop, change direction, and then speed back up to the original rate.
10. To make the lowercase letter **m**, stand about 0.5 meters away from the CBR. When data collection begins, you should move away from the CBR at a constant, but not slow rate. To make the curved top on the **m**, begin slowing down shortly before you wish to change directions. Slow your rate to a stop and then immediately begin to slowly speed up in the opposite direction until you are moving at your original rate. When you are halfway back to your starting position reverse direction abruptly and move away from the CBR at the same rate you were moving before changing direction. Once again, slow down gradually until you stop and immediately begin speeding up and moving back to the starting position.

11. The plot should resemble the one shown.



12. The walker would have the same motion, but he or she would move toward the CBR from across the room at the start.

Going Further

1. The key factor is the rate at which the walker changed direction. If the change was accomplished by gradually slowing down, changing direction, and gradually speeding up, the edges are rounded. If the change in direction is sudden with virtually no change in speed before or after the direction change, the corner is sharp. This occurs because when your rate is slowing, you are covering less distance in a given amount of time. Over a period of time, this results in the gentle rounding of the plot.
2. A circle cannot be made because the horizontal axis represents time. Every point will always be plotted to the right of the previous point, and so no looping back would be possible.
3. Answers will vary. Movement must always be to the right when writing out the letter.

4. Answers will vary. The key factor will be vertical or backward movement when writing the letter.
5. No letter or shape could be created that involves looping backward or moving vertically when writing the letter because the x axis represents time, and you can't go backward in time, nor can you make it stand still.

Activity 10 — Swing Thing

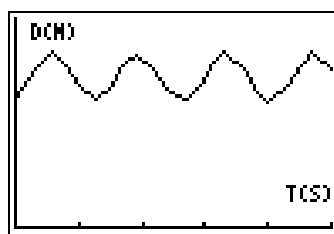
Collecting the Data

- ◆ Be sure that as the pendulum swings, it does not get closer than 0.5 meters to the CBR at any time.
- ◆ Keep the pendulum's amplitude small so that it does not move out of the CBR's detection range as it swings from one extreme to the other.

When your students perform this activity, the results will look similar to the examples below.

Note: The data in these tables is simulated. Actual data will be slightly different.

List L1	List L2
0	0.58
0.3	0.71
0.6	0.78
0.8	0.72
1	0.63
1.3	0.57
1.5	0.62
1.7	0.72
1.9	0.77
2.2	0.71
2.4	0.61
2.7	0.57
2.9	0.63
3.1	0.72
3.3	0.78
3.6	0.71
3.8	0.62
4.0	0.56
4.3	0.63
4.5	0.73
4.7	0.78
5.0	0.71



Looking at the Results

1. For the practice data, almost 4 complete cycles are shown. For a collection time of 15 seconds, the plot should show about 12 cycles.
2. First peak = 0.6 seconds
Second peak = 1.9 seconds
3. Period = 1.3 seconds

4. Answers will vary. Generally, the period does not depend on the mass of the pendulum.
5. Answers will vary. The period will decrease; it should be about 1 second.
6. Changing the weight of the pendulum's hanging object causes its period to remain the same, and decreasing its length causes its period to decrease.

Going Further

1. The period was not divided in half, indicating that pendulum length and period are not directly related. In fact, the pendulum length varies with the square of the period.
2. Frequency for the long-string pendulum is about 0.7 cycles per second; for the short-string pendulum, about 1 cycle per second.
3. If the pendulum's length increases, its frequency decreases. If the pendulum's period is tripled, its frequency would be one third its original value.