TEXAS INSTRUMENTS

Real-World Math with the CBL™ System

25 Activities Using the CBL and TI-82

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TABLE OF CONTENTS

Name ______________________________________ Date ________________________

SOUR CHEMISTRY Activity 14

Chemists quantify the relative acidity or alkalinity of a solution by measuring its pH on a scale ranging from 0 to 14. A neutral substance, such as distilled water, has a pH of exactly 7. A pH lower than 7 suggests an acidic solution, while a pH higher than 7 indicates that a solution is basic.

Different pH levels must be maintained throughout the body in order for a person to remain healthy. Excessively high or low pH levels often result in discomfort or irritation. For example, common indigestion or upset stomach usually indicates the presence of excessive amounts of stomach acids. This condition can sometimes be alleviated by ingesting an antacid tablet, or by drinking a solution such as Alka-Seltzer® and water, designed to neutralize these acids and raise the pH level in the stomach.

In this activity, the conditions found in an acid stomach will be simulated using a solution of lemon juice and water. The effectiveness of an antacid remedy will be tested by monitoring the pH of the solution after an effervescent antacid tablet has been added to it. The resulting data will be modeled using a modified exponential function.

YOU NEED:

1 CBL Unit
1 TI-82 Calculator with Unit-to-Unit Link Cable
1 Vernier pH Meter System with CBL-DIN adapter
7 oz. Drinking Cup
Distilled Water (about 3 or 4 ounces per trial)
Lemon Juice (about 10 drops per trial)
Eyedropper
Effervescent Antacid Tablets (for example, Alka-Seltzer®) one per trial

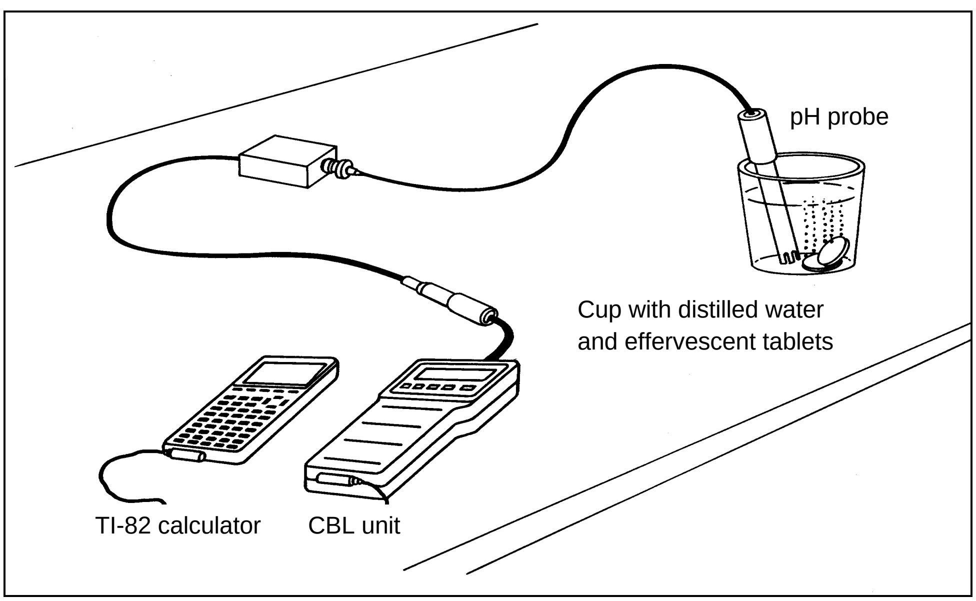

Figure 1

INSTRUCTIONS:

You will be instructed how to mix the lemon-juice-water solution when you run the activity program. If you decide to perform more than one trial, thoroughly rinse out the cup you are using before repeating the activity. Any residue in the cup may cause erroneous pH readings.

1. Start the CHEM program on your TI-82 calculator.
2. Follow the instructions on the TI-82 screen to complete the activity.

ACTIVITY DATA:

Your data plot should show pH values that increase rapidly at first, then level off.

- If your data plot is not satisfactory, press [CLEAR] [ENTER] to do another trial. If you need to perform another trial, be sure to thoroughly rinse out the cup you are using before repeating the activity since residue in the cup may cause erroneous pH readings.
- If you are satisfied with the data you've collected, sketch a plot of your pH vs. time data on the axes provided in Figure 2.

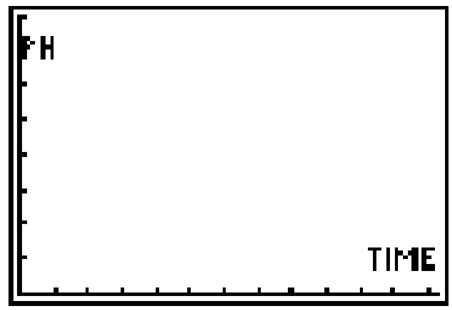

Figure 2

QUESTIONS:

1. The theoretical model for the pH vs. time data is a modified exponential function. We will attempt to fit our data with a curve of the form:

$$y = A(1 - B^x) + C$$

where y represents the solution's pH at any time, x. In this model, C represents the solution's initial pH, that is, the y-intercept. Press [TRACE] and identify this initial value. Round the value to the nearest tenth and record it in the space below:

C = ______________

2. Notice that, as time increases, the pH readings begin the approach a constant value as the curve flattens. Press [GRAPH], then press [2nd] [DRAW] [3] to put a horizontal marker on the screen. Use the [▲] [▼] keys to move this marker up and down on the screen. Use it to estimate the y value that the pH vs. time curve is approaching as the time values become larger and larger. Record this value in the space below:

pH approach value = ______________

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Name ____

3. The approach value you just found is related to the sum of the constants in the modeling equation. Given the fact that $0<B<1$, explain why the pH approach value is equal to $A + C$.

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Use the information above, together with the approach value found in question 2 and the constant *C* found in question 1, to solve for *A*. Record this value in the space provided:

$A =$ ______________

4. Press [Y=] and move the cursor to the first unused function register. Enter the expression *A*(1 - B^X) + C* and then press [2nd] [QUIT] to return to the home screen. Enter the value of *A* found above, then press [STO▸] [ALPHA] [A] [ENTER] to store this value to variable A on your calculator. Repeat this procedure to store variable C.

To obtain a good fit, you will need to adjust the value of *B*. Use the method described above to store different numbers to the variable B. Start with *B = 0.5*. View the graph for each value of *B* you test by pressing [GRAPH] after a new value has been stored to B. Experiment until you find one that provides a good fit for the data. Record the *B* value that works best in the space below. Round this value to the nearest hundredth.

$B =$ ______________

5. Use your own words to briefly describe how the value of *B* affects the shape of the modeling curve.

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6. How would adding more drops of lemon juice to the starting solution affect the resulting plot of pH vs. time for this activity? Which variable(s) in the equation $y = A(1 - B^x) + C$ would change, if any?
Hint: Adding more lemon juice would make the initial solution more acidic (that is, it would have a lower pH at the start).

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7. How would adding two antacid tablets to the lemon-water solution rather than one tablet affect the shape of the pH vs. time curve? Would any of the constants in the equation $y = A(1 - B^x) + C$ be different? Explain your reasoning.

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8. Suppose you are asked to compare the effectiveness of two different brands of antacid tablets. What variable in the modeling equation $y = A(1 - B^x) + C$ would give the best indication of how well a tablet works?
Hint: Which variable would affect the speed of the relief?

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EXTENSION:

The equation used in this activity, $y = -Ab^x + (A + C)$, is actually a modified version of the basic exponential equation, $y = AB^x$. Describe how $y = AB^x$ can be transformed into the desired modeling equation using reflections and shifts.
Hint: Work backwards by distributing A and re-grouping to obtain $y = -Ab^x + (A + C)$.

SOUR CHEMISTRY Activity 14

ACTIVITY NOTES:

1. Be sure to use an effervescent antacid tablet that contains sodium bicarbonate. Many antacids do not dissolve readily in water, making them ineffective for the purpose of this activity.
2. Distilled water, which has a pH very close to 7, is preferable in this activity. The pH of tap water is variable and could change the number of drops of lemon juice required to produce the proper initial condition.
3. When the activity is completed, use distilled water to rinse clean the pH probe so as not to contaminate the storage solution.

SAMPLE DATA:

See Figure 2.

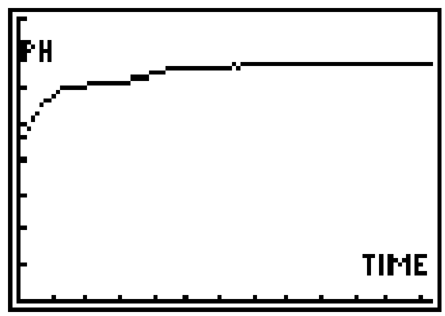

Figure 2 completed

ANSWERS TO QUESTIONS:

1. *C* = 4.40.
2. pH approach value = 6.71.
3. *A* = 2.31.
4. *B* = 0.85.
5. The value of *B* affects the steepness of the curve.
6. Adding more drops would shift the plot downward. The initial pH value would be lower, lowering the value of *C*. As well, the *A* value would be lower since the approach value would be lower.
7. The curve would be steeper if two tablets were used; this would cause the *B* value to be lower (closer to zero). The *A* value would be higher, raising the approach value.
8. The *B* value influences the steepness of the curve; the closer it is to zero, the faster the neutralization occurs.

Name ______________________________________ Date ________________________

JUMP! Activity 22

How high can you jump? What is the average jump height for your class? How does your jump compare with other jumps? One way to answer these questions would be to measure the jump heights for all the students in your class and then analyze this data statistically.

In this activity, you will use a light sensor and a CBL to measure how long you are in the air during a jump. This "hang time" will be used to calculate the height of your jump. The data set made up of the jump heights for all the students in your class will be analyzed using the statistical tools of the TI-82 calculator. Important features of this data set will be summarized in the form of a special graph called a *boxplot*.

YOU NEED:

1 CBL Unit
1 TI-82 Calculator with Unit-to-Unit Link Cable
1 TI Light Probe
1 Laser or Laser Pointer

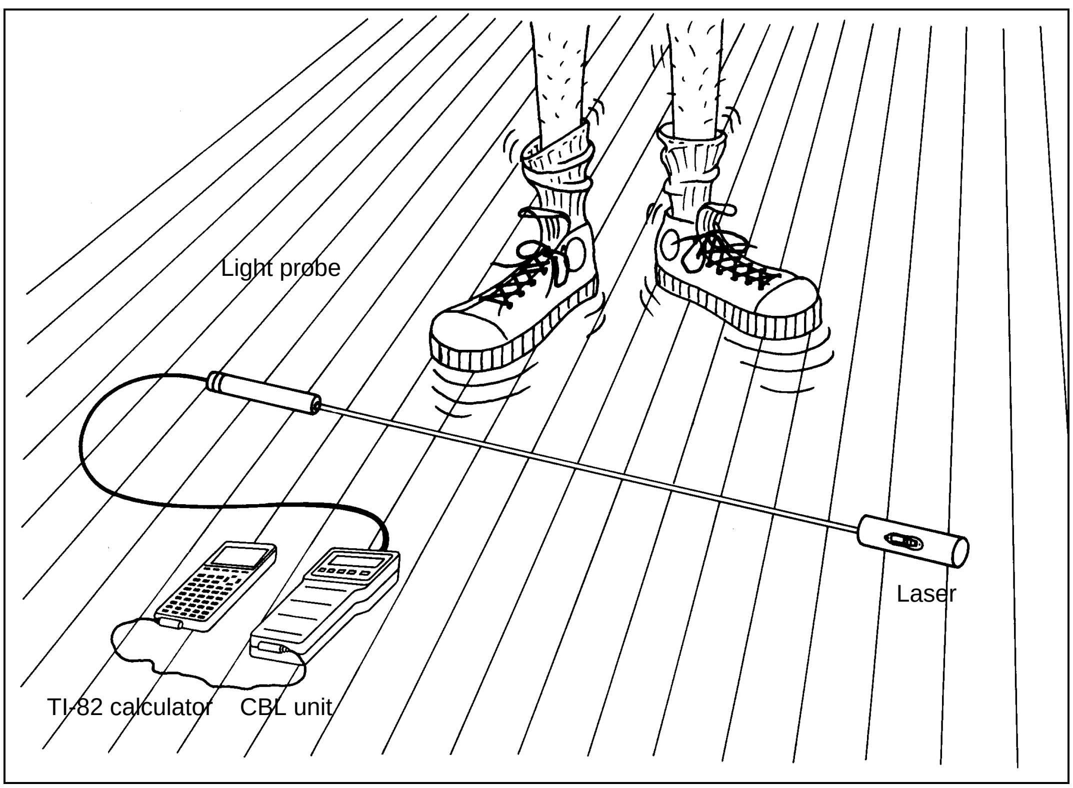

Figure 1

INSTRUCTIONS:

1. Position the laser and light sensor about three feet apart, as shown in Figure 1, so that the laser is shining directly into the sensor.
2. In this activity, you will stand so as to block the beam, then jump straight up and down, as directed. The time the beam is unblocked is detected by the CBL. This “hang time” value will be used to compute your jump height.
3. You will have an opportunity to jump more than once, but only your last attempt will be kept as part of the data set.
4. Run the JUMP program on the TI-82 calculator.
5. Follow the instructions on the TI-82 screen to complete the activity.

QUESTIONS:

1. What are the minimum and maximum jump heights for your class data? To find these values you will first need to order the data values from smallest to largest. To do this press [STAT] [2] to copy the **SortA(** command to the home screen. Then press [2nd] [L_1] [)] [ENTER] to sort the data. Press [STAT] [ENTER] to view the sorted data in list L_1. Use the arrow keys to scroll through the list. Identify the smallest and largest jump heights and record them below:

Minimum height	
Maximum height	

2. There are many ways to describe the “average” value for a set of numbers. One way is to compute the *median*. The median is the middle number of an ordered set of data. If there is an even number of values in the data set, the median is the average of the two middle values.

   Press [STAT] [ENTER] to view the sorted data in list L_1. Use the arrow keys to scroll through the list. Your position in the list is noted in parentheses at the bottom of the screen. Identify the middle value (or the average of the two middle values), and record this number in the space below:

   Median: ____________________

Name ____

3. The TI-82 has a built-in feature that can calculate and display a summary of important statistical information for a given list of data. To perform this operation on the data in list L_1 press [STAT] [▶] [ENTER] [ENTER]. Press [▼] several times to move to the bottom of the list of statistics. The minimum, maximum, and median values are denoted minX, maxX, and Med, respectively in the list. Do these numbers match the ones you calculated in questions 1 and 2 above?

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Two other important values listed in the statistical summary are the *lower quartile* (denoted Q1) and the *upper quartile* (denoted Q3). These numbers represent the medians of the lower and upper halves of the data respectively. Record these values in the space provided below:

Lower quartile: ____________________

Upper quartile: ____________________

4. A special type of graph, called a *box-and-whiskers* plot or *boxplot* for short, can be used to provide a statistical picture of a data set. It gives a graphical representation of the minimum, lower quartile, median, upper quartile, and maximum by displaying a view of the data distribution. To create a boxplot for the jump height data, press [2nd] [StatPlot] [ENTER] [ENTER] to turn on **Plot1**. Use the arrow keys to move around the screen; press [ENTER] to highlight the plot features so that your TI-82

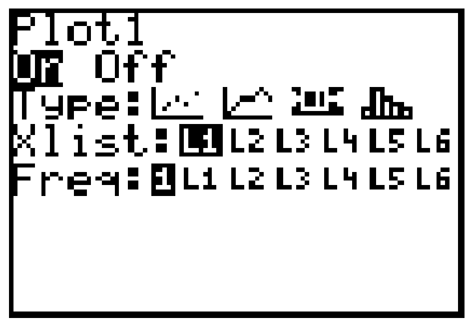

Figure 2

display matches the one in Figure 2. Press [ZOOM] [9] to view the boxplot. Make a sketch of your boxplot in the space provided in Figure 3. Press [TRACE] and use the arrow keys to move the cursor along the plot.

Label the minimum, maximum, median and quartile values on your sketch.

Figure 3

5. Notice that the *box* part of the plot really represents the middle portion of that data and the *whiskers* stretch to the lowest and highest numbers in the data set. The size and location of the box tell us certain things about the data. A large box indicates that the data is spread out, while a smaller box means the data is clustered. Discuss the size and location of the box part of your plot; describe how it relates to the jump heights for your class.

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6. Is the median located near the center of the box? What does the location of the median line in the box tell you about the distribution or arrangement of jump heights for the middle half of the data?

7. The length of the whiskers on the boxplot gives a hint as to the distribution of the data. If one whisker is significantly longer than the other, we say the data is *skewed* in the direction of the longer whisker. This just means that the data is bunched together near the shorter whisker. Describe the whiskers on your plot. What do the whisker lengths tell you about the jump heights for your class?

8. The nature of a boxplot is sometimes distorted by data values known as *outliers*. An outlier is a number that is set apart from the rest of the data set because it is significantly lower or higher than any other number in the set.

   The presence of an outlier might cause you to think that the data is skewed in one direction or another when it really is not. Press [STAT] [ENTER] and use the arrow keys to scroll through the list. Pay close attention to the numbers at the very beginning and very end of the list. Can you identify any outliers in your data set? If so, how does this change your answer to question 7, if at all?

9. Describe how your boxplot would be affected if one of the jumpers had a sprained ankle and was able to jump only 1/2 inch off the ground.

10. Suppose that the highest and lowest jumps were removed from your data set. How would the median, lower quartile and upper quartile values change, if at all?

Name ______________________________________

EXTENSION:

Another way to analyze the data you collected in this activity is to create a *histogram*. A histogram is simply a graphical representation of the number of times each jump height or range of jump heights occurs. Press [2nd] [StatPlot] [ENTER] to access **Plot1**. Select **histogram** as the type of plot.

Before you view the histogram you will need to manually fix the viewing window. Press [WINDOW]. Choose a number a few inches less than the smallest jump height for *Xmin* and a number a few inches greater than the largest jump height for *Xmax*. Let *Xscl = 2*; this will group the jump height data by 2-inch intervals. Let *Ymin = 0*. Choose *Ymax* equal to half the number of students in your class. Set *Yscl = 1*.

Press [GRAPH] to view the histogram. You may wish to adjust the window settings after you view the plot.

Use your own words to describe the data features summarized in this graph. Are the statistical features depicted in the histogram consistent with those shown in the boxplot you created earlier? Discuss the similarities and differences between these two plots. What are some advantages and disadvantages to using each type of plot to describe a set of data?

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JUMP! Activity 22

ACTIVITY NOTES:

1. If you are using a laser pointer, do not keep it turned on manually. Instead, use a twist tie or some strong tape to keep the laser turned on. This will help stabilize the path between the laser and the light sensor.
2. It is important that students interrupt the laser beam path before and after their jump. They should hold their position for a few seconds after they land since the CBL could still be sampling at that time.
3. General features and trends are sometimes hard to detect for small data samples. For best results, use at least 25 jumpers in the class sample. You may wish to combine data sets from several classes for this activity.

SAMPLE DATA:

See Figure 3.

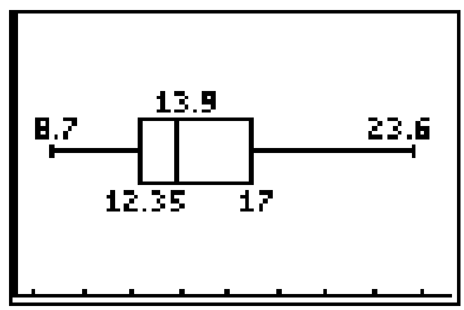

Figure 3 completed

ANSWERS TO QUESTIONS:

1. The minimum height is 8.7 inches; the maximum height is 23.6 inches.
2. The median is 13.9 inches.
3. Yes, they match. The lower quartile is 12.35 inches; the upper quartile is 17 inches.
4. See Figure 3.
5. The box is relatively small, implying that the data is somewhat clustered between 12.35 and 17 inches.
6. The median line is relatively centered. The middle half of the jump heights are somewhat clustered toward the lower quartile.
7. The data may be slightly skewed to the right. This implies that more students recorded smaller jumps than recorded larger jumps.
8. There are no identifiable outliers for the sample data set.
9. The left whiskers would be extended to the left. The outlier point might cause you to think that the data is skewed to the left when it actually is not.
10. The median would be unaffected. The lower quartile would become slightly larger, while the upper quartile would become slightly smaller.