Motion and Sound: Applications of the Sine Wave

Milford High School

click below to view the movie

Name(s) ________________________

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Block_____ Date______________

Modeling Distance/Time Graphs with a CBL2 and Motion Detector

Each team should have the following:

Equipment: 1 CBL2 Unit, 1 TI-83 Plus Calculator, 1 Unit-to-Unit Link Cable, 1 Vernier Motion Detector 2, 1 Dig/Sonic Cable, 1 Motion Detector Clamp

Setting up the CBL2 (Calculator Based Laboratory)

1. Make sure that the TI-83 Plus is off.
2. Connect the CBL2 and the TI-83 Plus with the link cable. **Be sure** the connections are tight.
3. Verify that the TI-83 Plus has the EasyData Application (This software controls the CBL2 and how it collects data).
   - Turn on the calculator.
   - Press [APPS]. Press [▲] or [▼] to highlight **EasyData**.
4. Attach the clamp to the back of the Vernier Motion Detector 2.
5. Plug the Motion Detector into the CBL2 using the Dig/Sonic Cable into the ports labeled **DIG/SONIC**.
6. Press [APPS]. Press [▲] or [▼] to highlight **EasyData**. Press [ENTER] to launch the application.
7. EasyData automatically identifies the Motion Detector, loads its calibration factors, and displays the name of the sensor, as well as the unit of length measurement in meters. It also loads a default motion experiment.
8. To change the settings of the experiment, from the main menu screen, select **Setup** (Press [WINDOW]).
9. Press [▲] or [▼] to have the arrow point at **2: TIME GRAPH…**. Press [ENTER] to view the **Time Graph Settings** screen.
10. Select **Edit** (press [ZOOM]). You will be prompted to ‘Enter time between samples in seconds:’. Enter **.1** seconds and select **Next** (Press [ZOOM]).
11. You will be prompted to ‘Enter number of samples to collect:’. Enter **150** and select **Next** (Press [ZOOM]).
12. Your Time Graph Settings will be displayed and your Experiment Length should read 15 seconds. Select **OK** (Press [GRAPH]).

Running the EasyData Application

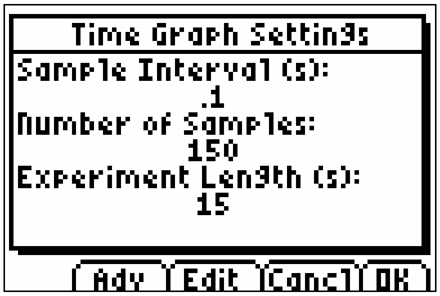


Diagram #1

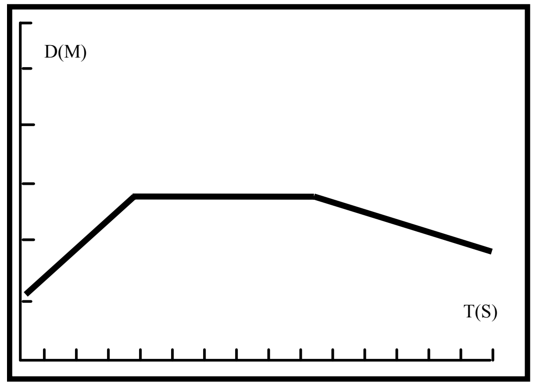


Diagram #2

Using the settings in Diagram #1 above, we will demonstrate how to create the graph shown in Diagram #2 above. Remember that the CBL2 can measure from 0.15 to 6 meters in Real-time mode and that the horizontal axis, T(S), is measured in seconds) with a range of 15 seconds and the vertical axis, D(M), is measured in meters with a range of 6 meters. [Note: the teacher will demonstrate this first, and then you will create a similar graph in your groups] To begin collecting data, select **START** from the main menu (Press ZOOM).

Answer the following questions based on your experiences with the above graph.

1. In what direction did you walk in order to get the graph to go uphill?

2. What did you do in order to get the graph to be horizontal?

3. In what direction did you walk in order to get the graph to go downhill?

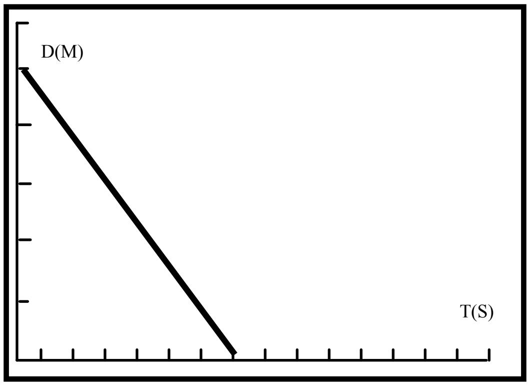
4. What else is different between your walk as the graph goes uphill versus downhill?

5. How would you have to walk in order to obtain a vertical line?

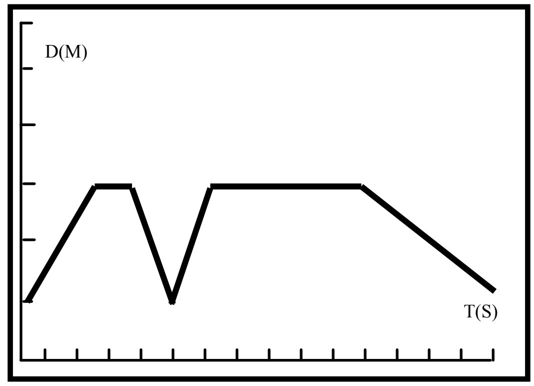
6. How would the rate of your walk change if you wanted the graph to be curved?

***Please do not continue until after the class has discussed the above questions**

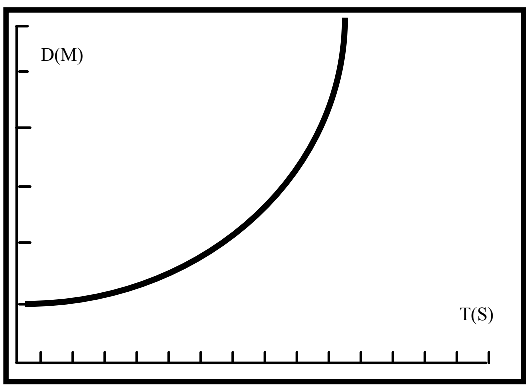
In your groups, use the CBL2 and the graphing calculator to walk out the following graphs. Be sure to write a description of how you walked directly on the graph. Include the direction and rate you walked, how far you started from and ended relative to the CBR. Be sure to show your teacher each graph on your calculator with the written descriptions on the paper and obtain your teacher's initials.



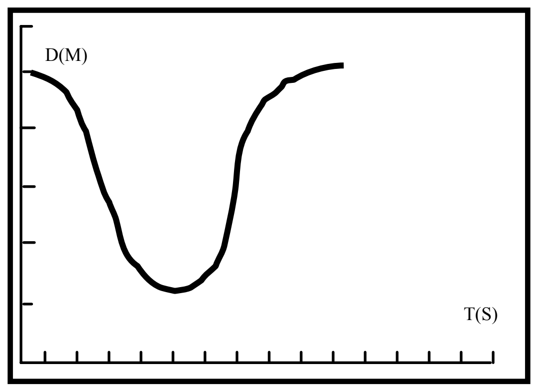
Teacher Initials __________



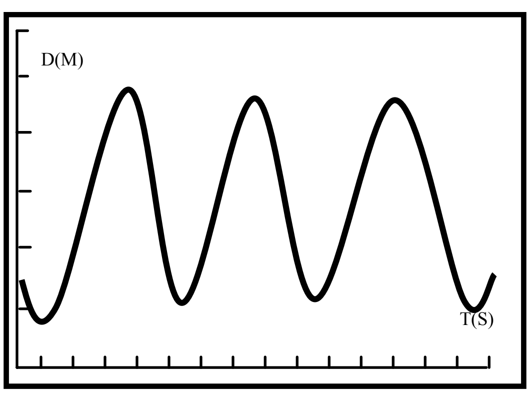
Teacher Initials __________



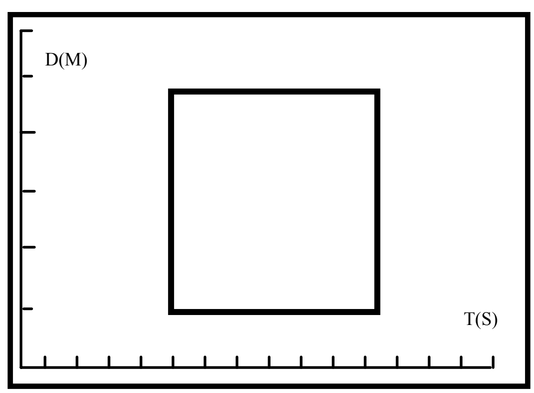
Teacher Initials __________



Teacher Initials __________



Teacher Initials __________



Teacher Initials __________

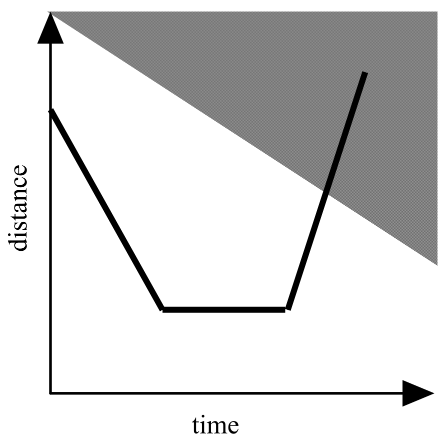
Assignment – Modeling Distance/Time

Name__________________ Date________

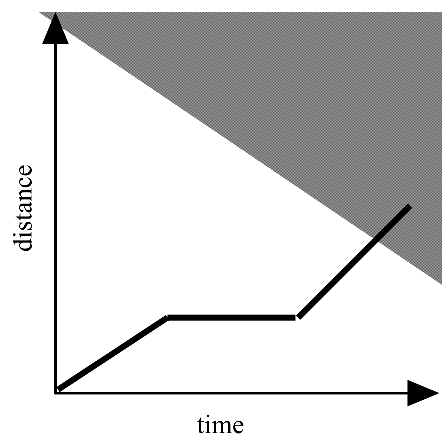
1. Match each description with the graphs below. (**Note:** there are three descriptions and four graphs so one graph will not have a description). Explain your reasoning. Be sure to write a description of what is happening directly on each graph that you match.

   a. I left home (walking at a pace that slowed as I got tired) when I realized I had forgotten my books. I went back to pick them up (quickening my pace) and then continued on my way.
   b. I was driving along and then had a flat tire. Once I fixed it, I continued on my way.
   c. I started out calmly but sped up when I realized I was going to be late.

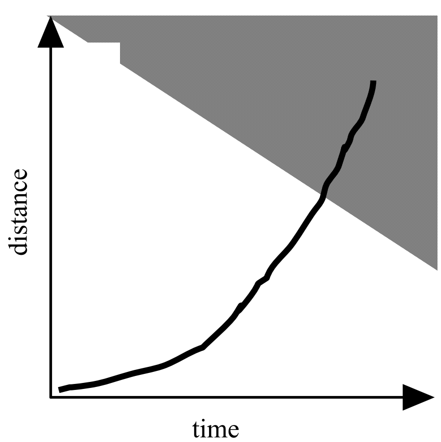
i)



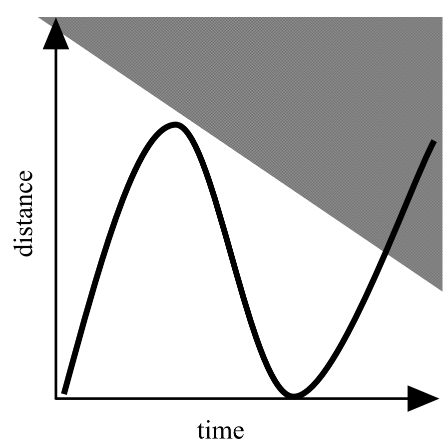
ii)



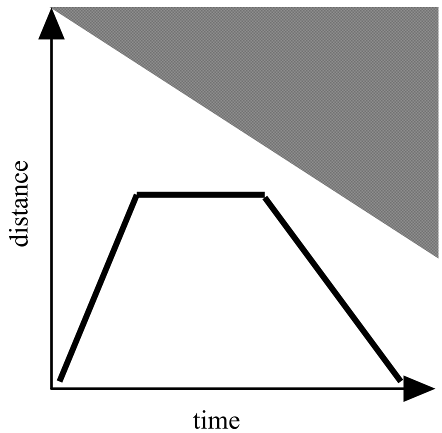
iii)



iv)

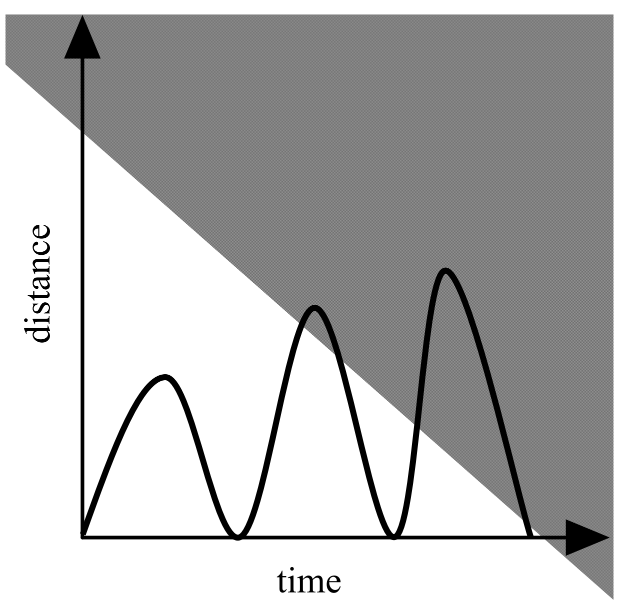


2. Write a few sentences giving a possible scenario for the kind of motion the graph below might represent. Be creative in your explanation.



3. Think about the CBL2 activity. How did the “rate at which you walked” affect the graph? Explain.

4. Write a few sentences providing a possible scenario for the type of motion the graph below might represent. Be creative. Write a description of what is occurring directly on the graph.



Name ______________________

Partner's Name(s)______________________

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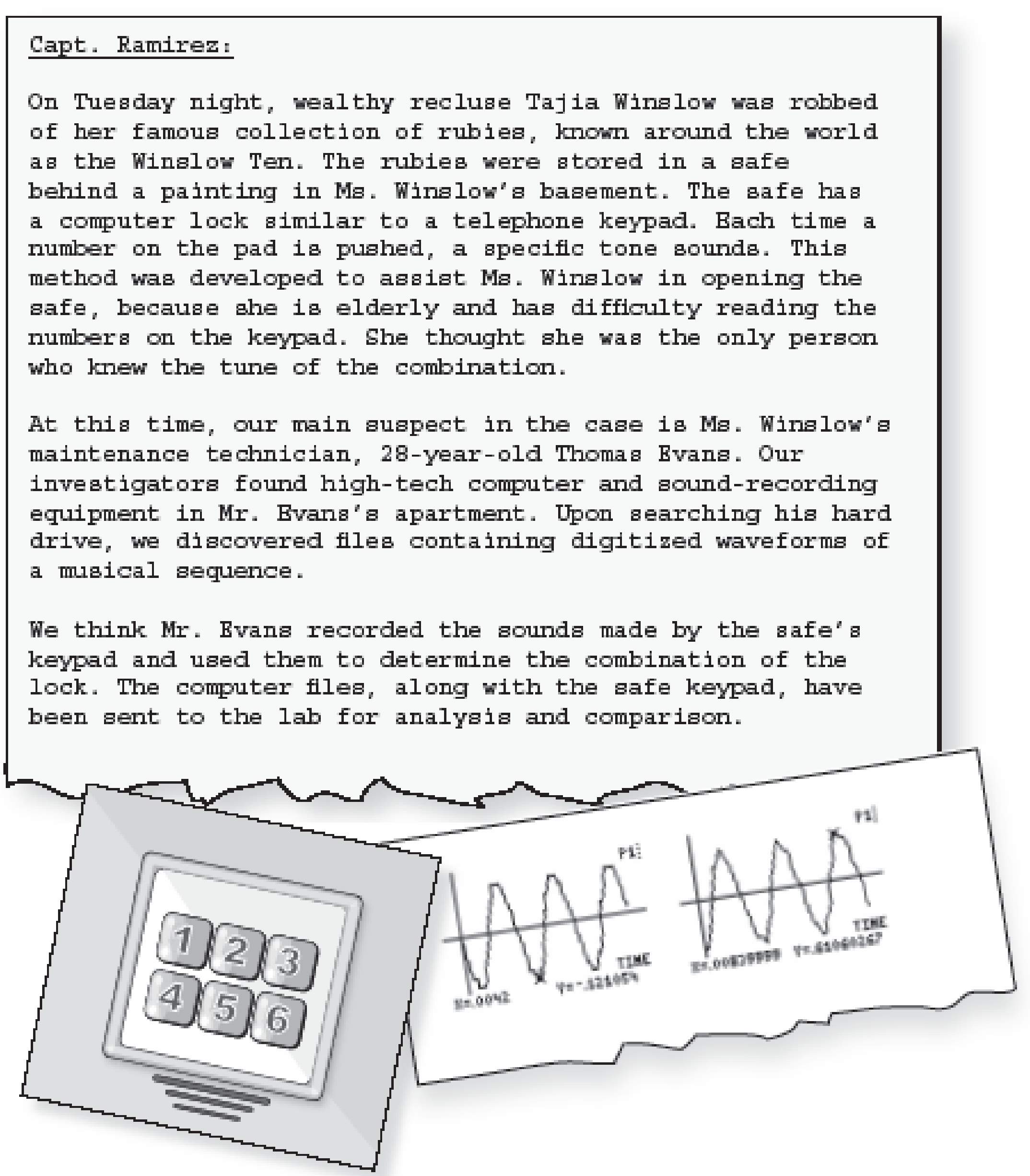
Block_____ Date______________

Name That Tune – Waveform Analysis



Capt. Ramirez:

On Tuesday night, wealthy recluse Tajia Winslow was robbed of her famous collection of rubies, known around the world as the Winslow Ten. The rubies were stored in a safe behind a painting in Ms. Winslow's basement. The safe has a computer lock similar to a telephone keypad. Each time a number on the pad is pushed, a specific tone sounds. This method was developed to assist Ms. Winslow in opening the safe, because she is elderly and has difficulty reading the numbers on the keypad. She thought she was the only person who knew the tune of the combination.

At this time, our main suspect in the case is Ms. Winslow's maintenance technician, 28-year-old Thomas Evans. Our investigators found high-tech computer and sound-recording equipment in Mr. Evans's apartment. Upon searching his hard drive, we discovered files containing digitized waveforms of a musical sequence.

We think Mr. Evans recorded the sounds made by the safe's keypad and used them to determine the combination of the lock. The computer files, along with the safe keypad, have been sent to the lab for analysis and comparison.

Equipment: 1 CBL2 Unit, 1 TI-83 Plus Calculator, 1 Unit-to-Unit Link Cable, 1 Vernier Microphone, 6 Tuning Forks of Different Frequencies, Tuning Fork Wedge Activator

Forensics Objective:
• identify the musical notes that make up the combination to a safe

Science and Mathematics Objectives:
• detect the waveform of a musical note, using a Microphone
• calculate the frequency of a musical note from the period of its waveform

Procedure:
1. Connect the CBL 2 to your calculator with the link cable.

2. Plug the Microphone probe into channel 1 (~CH1) of the CBL 2.

3. Load the EasyData application and set up to use the Microphone probe.

a) Press [APPS].

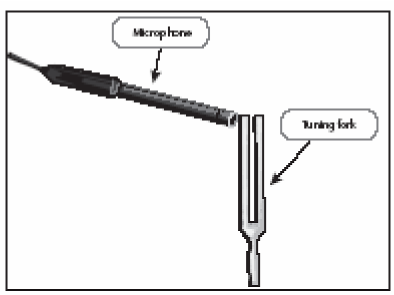
b) Use [▼] to highlight :EasyData. Press [ENTER] to start the application. The EasyData application will start automatically.

4. Collect data to determine the frequency of each tuning fork. The easiest way to do this is to split up the group so that one person holds the tuning fork, a second person holds the Microphone, and a third controls the calculator.

a) In the Evidence Record, write the number of the label found on the first tuning fork.

b) Strike the tuning fork with the soft hammer and then hold the fork straight up and down.

c) Hold the Microphone about 1 cm from the space between the prongs, as shown in the diagram below.



(Note: *Never* strike the tuning fork on a hard surface; it may change the waveform of the tuning fork.)

d) Select [Start] to start data collection. If you get a message about overwriting data, select [OK]. The waveform will appear on your screen within a few seconds. If a clear waveform image does not appear, repeat the analysis by selecting [Main] and repeating steps 4b–4c. Change the location of the vibrating tongs of the tuning fork until you get a clear waveform image. You may have to practice several times.

5. Once you have a clear waveform image , you are ready to analyze the waveform to calculate the period and the frequency (or pitch) of the note.

   a) Press and hold ▶ to move the cursor to a crest (highest point) of the waveform (exclude the initial crest).

   b) At the bottom of the display, you will see **X=** and **Y=**. The **X=** is the time (in seconds). The **Y=** is the amplitude of the sound wave. Record the time, **X=**, displayed at the crest of the waveform as *t*1 in the Evidence Record. Then move the cursor to the next crest, and record this time as *t*2 in the Evidence Record. The value *t*2 - *t*1 is the period, *T*, of the note. Record the value you calculate for *T* in the Evidence Record.

   c) Calculate the frequency, f, of the note using the equation $f = \frac{1}{T}$. Record the frequency of the tuning fork in the Evidence Record. The unit for frequency is s^{-1} or hertz (Hz). One hertz equals one cycle per second.

6. Repeat steps 4 and 5 with the remaining tuning forks.

7. Calculate the period and frequency of each of the notes on the Waveforms of the notes taken from Evans's Computer Hard Drive handout.

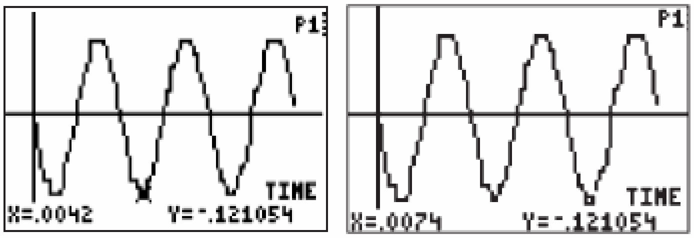
8. Compare the frequencies in the Evidence Record to the frequencies on Evans's computer hard drive. Determine the combination of notes that was stored on the hard drive, and record it in the Case Analysis.

Evidence Record:

Tuning Fork Number	**Time at First Crest, t_1 (s)**	**Time at Second Crest, t_2 (s)**	**Period, T (s)**	**Frequency, f (cycles/s or Hz)**

Waveforms of the Notes Taken from Evans's Computer Hard Drive

First note

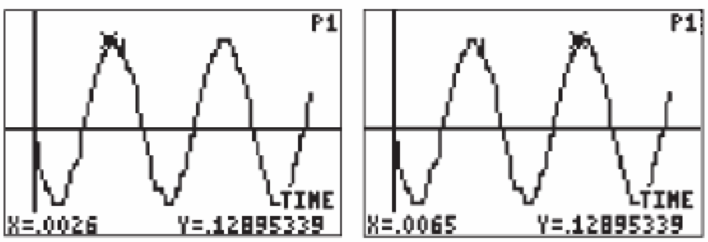


Period: ____________

Frequency: ____________

Note: ____________

Second note

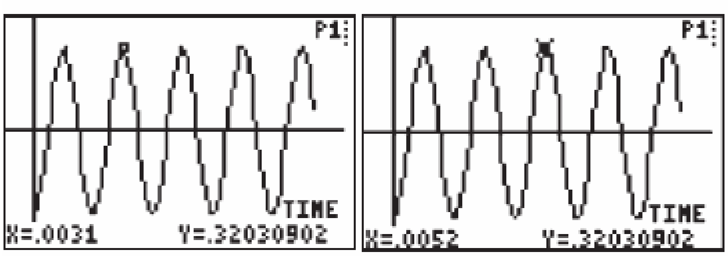


Period: ____________

Frequency: ____________

Note: ____________

Third note

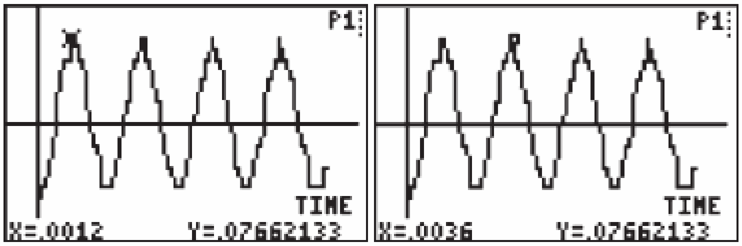


Period: ____________

Frequency: ____________

Note: ____________

Fourth note

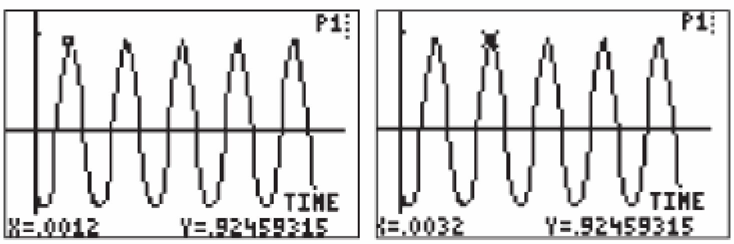


Period: ____________

Frequency: ___________

Note: ____________

Fifth note

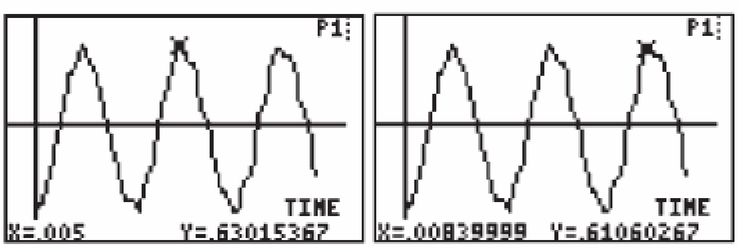


Period: ____________

Frequency: ___________

Note: ____________

Sixth note



Period: ____________

Frequency: ___________

Note: ____________

Case Analysis

List the order of tones in Evans's hard drive, using numbers on tuning forks: ____

1. Explain why the period and frequency of a waveform calculated using the time between two crests are the same as when using two troughs.

2. Like all waves, sound waves have a frequency and a wavelength. The speed of sound in air is about 340 m/s. Frequency is measured in cycles per second. Speed is measured in meters per second. Wavelength is measured in meters. Using this information, write an equation that shows how you can calculate the wavelength of a wave if you know its frequency and speed.

3. Using the equation you wrote for question 2, calculate the wavelength of each of the notes produced by the tuning forks in your Evidence Record. Show all your work.

4. Using the same equation, explain how frequency and wavelength are related.

5. The police determined that the correct combination for the safe corresponded to the following order of wavelengths: ___________________________.
Did Evans record the safe combination, or was his recording of another combination of notes? How do you know?

Rubric for Name That Tune – Waveform Analysis   (48 pts)

1)(upto 6 pts) Time on Task __________

2)(upto 12 pts) Evidence Record __________

based on completing chart and accurately finding period and frequency

3)(upto 12 pts) Waveforms of the Notes Taken
from Evan's Computer Hard Drive __________

based on accurately finding period, frequency, and note

4)(up to 15 pts) Case Analysis

based on answering the questions in detail and showing work when appropriate

order of tones(1) ___________
question #1   (2) ___________
question #2   (2) ___________
question #3   (6) ___________
question #4   (2) ___________
question #5   (2) ___________

5)(up to 3 pts)   A quality paper is submitted ___________

based on neatness and organized work

total points ____________/48

Name ______________________

Partner's Name(s)______________________

____

Block_____ Date______________

Sinusoidal Curves – The Pendulum

Each team should have the following:

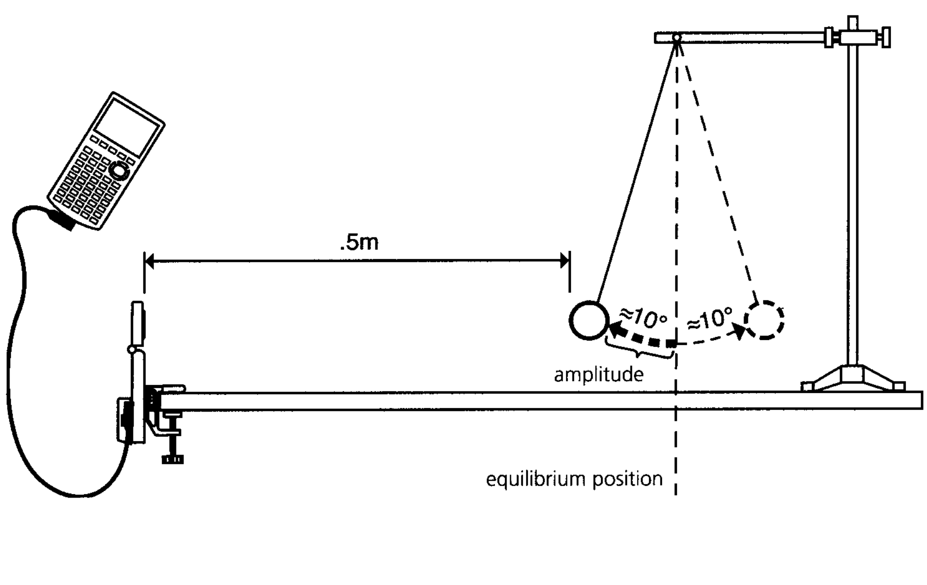
Equipment: 1 CBL2 Unit, 1 TI-83 Plus Calculator, 1 Unit-to-Unit Link Cable, 1 Vernier Motion Detector 2, 1 Dig/Sonic Cable, 1 Motion Detector Clamp, Pendulum, Stopwatch, Meter Stick, Masking Tape

If a pendulum is pulled back and released, it will swing back and forth over time with a noticeable pattern occurring. It will eventually stop, but over a short time period the pendulum exhibits simple harmonic motion. This motion is modeled by a periodic function.

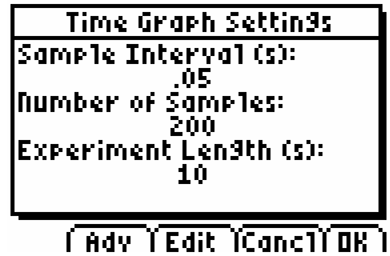
In this activity, you will collect the data from the motion of a pendulum. Then a periodic function will be found that models that motion. Its parameters will be related to the time for one period, the distance it was pulled back, and how far it is from the motion detector.

Instructions

1. Set up the CBL2 and pendulum and align it so that it swings in direct line with the CBL2 (*See the diagram below*). Mark the equilibrium position with masking tape. This should be between 0.30 and 1.00 meter from the CBL2. Pull the pendulum back from its rest position towards the CBL2 so that it is no closer than 0.25 meter from the CBL2. Use masking tape to mark the spot to which it is pulled.



2. Run the EasyData application on your calculator and enter the following setup instructions:



3. When the pendulum is released, one cycle will be the motion of the pendulum in leaving its starting position and returning there. Using a stop watch, time at least three cycles of the swing. ______________________

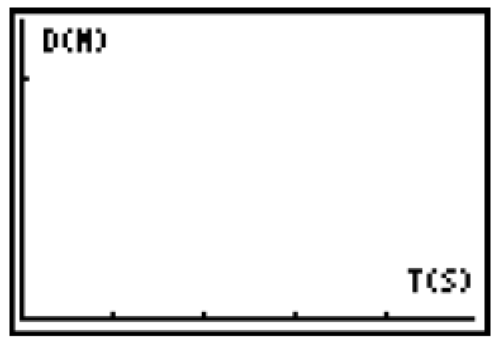
4. Find the average time for one cycle.

   ____

5. Begin collecting data using your calculator as the pendulum is released.

Data Collection

1. The graph should appear to be a sine or cosine graph. If you are not satisfied with the results, return to the main menu and restart the data collection. Sketch a graph of the Distance-Time in the space provided.



2. Record the distance in meters from the CBL2 to the pendulum's equilibrium position.

   ____

3. Record the distance in meters from the pendulum's rest position to the point it was pulled back.

   ____

Questions

1. Use ▶ to trace along the curve to the first maximum point. Record the values below as (x_1,y_1). Trace to the next minimum point minimum point after the first maximum point and record this value as (x_2,y_2). Trace the next maximum point and record below as (x_3,y_3).

   First Maximum: x_1 = __________ y_1 = __________

   Minimum: x_2 = __________ y_2 = __________

   Second Maximum: x_3 = __________ y_3 = __________

2. Find the amplitude.

   A = ____________________________

   Compare this value to the distance from the pendulum's equilibrium position to the point it was pulled back found in **Data Collection** question #3.

   ____

3. The average between the maximum and the minimum values is the vertical shift. Find the vertical shift by adding the maximum (y3 or y1) and minimum (y1) together and dividing by two.

   D = ____________________________

   Compare this value to the distance from the CBL2 to the pendulum's equilibrium position found in **Data Collection** question #2.

   ____

4. The phase shift for a sine curve would be the time at which the first equilibrium occurs. Record the time the first equilibrium occurs below as C.

   C = ____________________________

5. Use the graph to find the period. Record as P.

   P = ____________________________

   Compare the period to the average time per cycle found in **Instructions** question 4.

   ____

6. The general equation of the sine curve is $y = A \sin (B(x - c)) + D$. Write the equation for the sine function that would model the motion of the pendulum.

   y = ____________________________

7. Exit the EasyData application, press [Y=], and enter your function in **Y1**. Press [GRAPH] to display both the scatter plot and your equation. How well does your equation fit the scatter plot?

   ____

8. The sine and cosine graphs only differ by a horizontal shift. Write the equation of the cosine function based on the horizontal shift that models the motion of the pendulum.

   ____

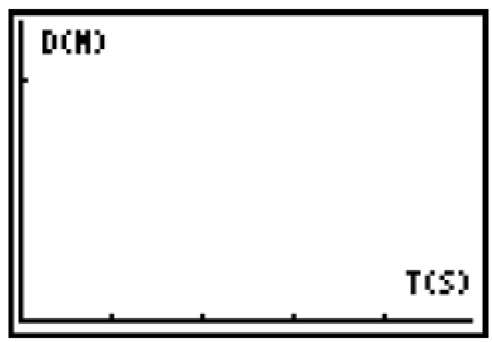
9. Press [Y=] and enter your function in **Y2**. Press [GRAPH] to display both the scatter plot and your equation. How well does your equation fit the scatter plot?

    ____

Use the 10-second time period again, but change some other factor in your experiment.

Data Collection

1. The graph should appear to be a sine or cosine graph. If you are not satisfied with the results, return to the main menu and restart the data collection. Sketch a graph of the Distance-Time in the space provided.



2. Record the distance in meters from the CBL2 to the pendulum's equilibrium position.

    ____

3. Record the distance in meters from the pendulum's rest position to the point it was pulled back.

    ____

4. Use a stop watch to time at least three cycles of the swing. Find the average time for one cycle. ____________________________

Questions

1. State the factor that you changed in this experiment. ________________________________

    ____

2. Use ▶ to trace along the curve to the first maximum point. Record the values below as (x_1, y_1). Trace to the next minimum point minimum point after the first maximum point and record this value as (x_2, y_2). Trace the next maximum point and record below as (x_3, y_3).

   First Maximum: x_1 = __________ y_1 = __________

   Minimum: x_2 = __________ y_2 = __________

   Second Maximum: x_3 = __________ y_3 = __________

3. Find the amplitude.

   A = __________________________

   Compare this value to the distance from the pendulum's equilibrium position to the point it was pulled back found in **Data Collection** #7.

   ____

4. The average between the maximum and the minimum values is the vertical shift. Find the vertical shift by adding the maximum (y3 or y1) and minimum (y1) together and dividing by two.

   D = __________________________

   Compare this value to the distance from the CBL2 to the pendulum's equilibrium position found in **Data Collection** #6.

   ____

5. The phase shift for a sine curve would be the time at which the first equilibrium occurs. Record the time the first equilibrium occurs below as C.

   C = __________________________

6. Use the graph to find the period. Record as P.

   P = __________________________

   Compare the period to the average time per cycle found in **Data Collection** #8.

   ____

7. The general equation of the sine curve is $y = A \sin(B(x - c)) + D$. Write the equation for the sine function that would model the motion of the pendulum.

   $y =$ ____________________________

8. Exit the EasyData application, press [Y=], and enter your function in **Y1**. Press [GRAPH] to display both the scatter plot and your equation. How well does your equation fit the scatter plot?

   ____

9. The sine and cosine graphs only differ by a horizontal shift. Write the equation of the cosine function based on the horizontal shift that models the motion of the pendulum.

   ____

10. Press [Y=] and enter your function in **Y2**. Press [GRAPH] to display both the scatter plot and your equation. How well does your equation fit the scatter plot?

    ____

Compare and contrast your results from both 5-second experiments below.

____

____

____

Grade = points earned for each question + points (out of 10) for time on task.

Grade = ______________________ + ____________________________ = _______/

Algebra 3/ Trigonometry Name____________________

Quiz Grade:__________ Date____________________

(There will be a loss of five points per day on late homework.
No late papers will be accepted after the assignment has been returned to students.)

Modeling Distance vs Time Graphs
With a CBL2 and Motion Detector

20% Time on Task during the lab

Each group member must be focused on his/her own group (and not on other groups). Each group member must participate in all aspects of the activity (set-up, take-down, controlling the calculator, performing the motion).

__________ / 20 pt

40% The CBL2 Lab

All graphs completed correctly with a complete explanation describing every aspect of the graph.

Graph 1: __________ / 4 pt

Graph 2: __________ / 8 pt

Graph 3: __________ / 8 pt

Graph 4: __________ / 8 pt

Graph 5: __________ / 8 pt

Graph 6: __________ / 4 pt

40% Homework

Question 1: __________ / 10 pt

Question 2: __________ / 10 pt

Question 3: __________ / 10 pt

Question 4: __________ / 10 pt