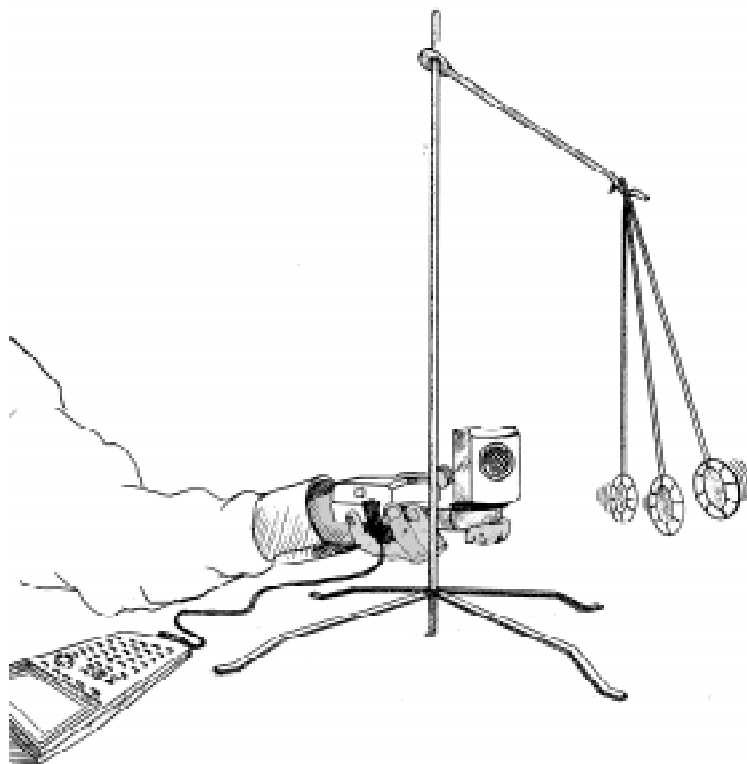Name _____

Date _____

EXPLORATIONS

ACTIVITY 14

Swinging Along

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.

You'll Need

♦ 1 CBR unit

♦ 1 TI-83 or TI-82 Graphing Calculator

♦ Pendulum (a yo-yo works well)

♦ Meter stick

♦ Masking tape

♦ Stopwatch

Instructions
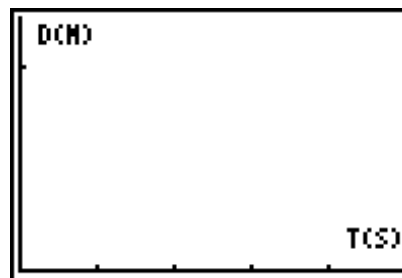
1. Press MODE. Make sure that the calculator is in **Radian** mode.

2. Setup the CBR and the pendulum as shown.

3. Run the **RANGER** program on your calculator.

4. Enter the setup instructions.

   a. From the **MAIN MENU** select **1:SETUP/SAMPLE** to access the setup menu.

   b. Press ENTER until the **REALTIME** option reads **no**.

   c. Press ▼ (the down arrow) to select the next line **TIME (S)** and press ENTER 5 ENTER to change the time to **5** seconds.

   d. Press ▼ to select the next line. Correct or verify the settings and press ENTER. Repeat until the options for each line read as shown at right.

```
MAIN MENU      ▶START NOW

REALTIME:   NO
  TIME(S):  5
 DISPLAY:   DIST
BEGIN ON:   [ENTER]
SMOOTHING:  LIGHT
   UNITS:   METERS
```

5. Mark the at rest position with masking tape. This should be between 0.75 and 1 meter from the CBR. Pull the pendulum back from its rest position towards the CBR so that it is no closer than 0.5 meter from the CBR. Use masking tape to mark the spot to which it is pulled.

6. When the pendulum is released, one cycle will be the motion of the pendulum in leaving its starting position and returning there. Time at least three cycles of the swing.

7. On the calculator, press ▼ until **START NOW** is selected. Press ENTER and follow the directions on the screen. Press ENTER on the calculator to begin collecting the data 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, press ENTER and select **5:REPEAT SAMPLE**. Sketch a graph of the Distance-Time in the space provided.

```
D(M)




                              T(S)
```

2. Record the distance in meters from the CBR to the pendulum's rest position as D.

   D = _____

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

$A =$ _____

4. Find the average time for one cycle and record as P.

$P =$ _____

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 after the first maximum point and record this value as (x_2, y_2). Trace to 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. Press ⬚ENTER and select **7:QUIT**. The distance from the maximum to the minimum is twice the amplitude. To find the amplitude, subtract the minimum (y_2) from the maximum (y_3 or y_1) and then divide by two. Compare this value to the distance from the pendulum's rest position to the point it was pulled back.

   $A =$ _____

   _____

3. The average between the maximum and the minimum values is the vertical shift. Find the vertical shift by adding the maximum (y_3 or y_1) and minimum (y_2) together and dividing by two. Compare this to the distance from the CBR to the pendulum's rest position.

   $D =$ _____

   _____

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

   $C =$ _____

5. The difference in time between the first two maximum values is the period. Find the period by subtracting x_3 from x_1. Compare the period to the average time per cycle found in **Data Collection** question 4.

   P = _____

   _____

6. The general equation of the cosine curve is $y = A\cos(B(x-C)) + D$ where

B is $\dfrac{2\pi}{P}$.

Find B by dividing 2π by the period.

$B = $ _____

7. Use the values of A, B, C and D found in questions 2 through 6 to write the equation for the cosine function that would model the motion of the pendulum.

$y = $ _____

8. Press $\boxed{\text{Y=}}$ and enter your function in **Y1**. Press $\boxed{\text{GRAPH}}$ 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. To write a sine function that models the pendulum's motion, only the phase shift will need to be changed. Trace to the first minimum point on the graph. The phase shift will be the x-value of the point halfway between the minimum and the next maximum. The y-value will correspond to the vertical shift. Trace to the point where the y-value is most nearly the value of D. Record the x-value as C.

$C = $ _____

10. Use the same values for A, B, and D along with the new value of C to write a sine function in the form $y = A\sin\left(B(x-C)\right) + D$ that models the motion of the pendulum.

$y = $ _____

11. Press $\boxed{\text{Y=}}$ and enter your function in **Y2**. Press $\boxed{\text{GRAPH}}$ to display both the scatter plot and your equation. How well does your equation fit the scatter plot?

_____