EXPLORATIONS

Activity 9

How Can a Clock Part Measure Gravity?

Objectives

- To measure the motion and calculate the acceleration of a simple pendulum
- To understand the effect that gravity has on the motion of a pendulum

Materials

- TI-73
- Unit-to-unit cable
- CBL 2™
- CBR™ with CBR to CBL 2™ cable, or motion detector
- 2 pieces of string (0.5 and 1.5 meters)
- One or more masses large enough to be seen by the motion detector
- Meter stick
- Ring stand with clamp
- Data Collection and Analysis pages (p. 78 – 80)

In this activity you will

- Make a simple pendulum.
- Use the CBL 2™ with a motion detector to measure the period of the pendulum.
- Calculate the acceleration due to gravity for your pendulum.

Problem

How does the acceleration due to gravity change for different pendulum lengths?

Introduction

For centuries, clocks have used pendulums to keep time. This is possible because the acceleration due to gravity is constant and measurable. As a result, clockmakers can design the pendulum on their clocks to swing back and forth at a constant rate that will keep time accurately. You have probably seen many clocks that use pendulums, such as grandfather clocks, cuckoo clocks, and others.

A simple pendulum can be used to determine the acceleration due to gravity. A simple pendulum swings back and forth with a relatively constant motion for short periods of time. The time it takes the pendulum to swing back and forth one time or complete one full cycle is known as its *period* (abbreviated T). The length of the pendulum can be varied, causing the pendulum's period to change. You can calculate the acceleration due to *gravity* (g) if you know the *length* (l) of the pendulum and the pendulum's *period* (T).

The formula you will use to calculate this is $g = \frac{T^2}{4\pi^2 l}$.

Hypothesis

Before testing, complete the **Hypothesis** section on the **Data Collection and Analysis** page.

Procedure: Collecting the Data

1. Attach your simple pendulum to the ring stand using the .5 m string. Also assign duties to the members of your lab group. One person needs to start the pendulum and another person needs to start the data collection.
2. Plug the motion detector into the **DIG/SONIC** channel on the CBL 2™.
3. Start the DATAMATE program.
4. The Main Screen is displayed. If **DIG:MOTION(M)** is displayed at the top of the screen, go to step 8. If **DIG:MOTION(M)** is not displayed, go to step 5.
5. Select **1:SETUP**.
6. Select **DIG.** Then select **1:MOTION(M)**.
7. Select **1:OK** to return to the Main Screen.
8. Make sure that there are no objects that might interfere with the pendulum's swing or with the motion detector as it measures the pendulum's swing.
9. Pull the mass back about 50 cm and release it.
10. When the pendulum is swinging steadily, select **2:START**. The CBL 2™ beeps twice and the motion detector starts clicking. The CBL 2 beeps again when it has finished collecting data.
11. The program displays three choices for graphing the data. Select **DIG-DISTANCE**.
12. The graph is displayed showing the data that was collected. Use [▶] and [◀] to trace the curve and record the time at the top of the first and second peaks in the table on the **Data Collection and Analysis** page.
13. Repeat steps 8 through 12 two more times, for a total of three trials.
14. Repeat steps 8 through 13 for the second pendulum length of 1.5 m.
15. To exit from the DATAMATE program, press [ENTER] to return to the Main Screen. Select **6:QUIT** and press [ENTER].

Data Analysis

Using the data you collected, answer the questions on the **Data Collection and Analysis** page to analyze your results.

Application

1. Predict how changing the weight or mass on the pendulum would change the results. Write your prediction on the **Data Collection and Analysis** page.
2. Follow your teacher's instructions and design an experiment to test your prediction or hypothesis.
3. After you have completed your experiment, write your conclusion on the **Data Collection and Analysis** page.

Data Collection and Analysis

Name ______________________________

Date ______________________________

Activity 9: How Can a Clock Part Measure Gravity?

Problem

How does the acceleration due to gravity change for different pendulum lengths?

Hypothesis

The acceleration due to gravity will (increase / decrease / remain the same) when the pendulum length is increased. (Circle the correct response.)

Data Collection

1. After each trial with the first pendulum length, use the data from the displayed graph and record the time at the top of the first and second peaks in the table below.

2. After all three trials, use the TI-73 to find the time for each period and the average period for all three trials.

First Pendulum Length = ___________ m

	Time for First Peak in Seconds (t_1)	**Time for Second Peak in Seconds (t_2)**	**Period (T) (t_2 - t_1)**
Trial 1			
Trial 2			
Trial 3			
Average Period			

3. After each trial with the second pendulum length, use the data from the displayed graph and record the time at the top of the first and second peaks in the table below.

	Time for First Peak in Seconds (t_1)	**Time for Second Peak in Seconds (t_2)**	**Period (T) (t_2 - t_1)**
Trial 1			
Trial 2			
Trial 3			
Average Period			

4. After all three trials, use the TI-73 to find the time for each period and the average period for all three trials.

Second Pendulum Length = ____________ m

Data Analysis

1. Use the time for the average period from the data tables above and calculate the acceleration caused by gravity for each length. Remember that the formula you will use is $g = \frac{T^2}{4\pi^2 l}$ where: T is the pendulum's period in seconds (s), l is the pendulum's length in meters (m), and g is the acceleration due to gravity in m/s^2.

a. Calculations for Length 1:

Pendulum's period (T) = ______________________________

Pendulum's length (l) = ______________________________

Acceleration due to gravity (g) = ______________________________

b. Calculations for Length 2:

Pendulum's period (T) = ______________________________

Pendulum's length (l) = ______________________________

Acceleration due to gravity (g) = ______________________________

2. The accepted value for g is 9.8 m/s^2. Compare the values you calculated in question 1 above with the accepted value. Was one closer to the correct value than the other?

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a. What could have caused your answers to be different from the each other?

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b. What could have caused your answers to be different from the accepted value? Be as specific as possible.

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3. If you want to get a more accurate answer, how would you change the experiment? What could you have done differently?

Application

1. Predict how changing the weight or mass on the pendulum will effect the results.

2. Discuss how changing the weight or mass on the pendulum actually affected the results.

Conclusion

The acceleration due to gravity will (increase / decrease / remain the same) when the pendulum length is increased. (Circle the correct response.)

Teacher Notes

Activity 9

How Can a Clock Part Measure Gravity?

Objectives

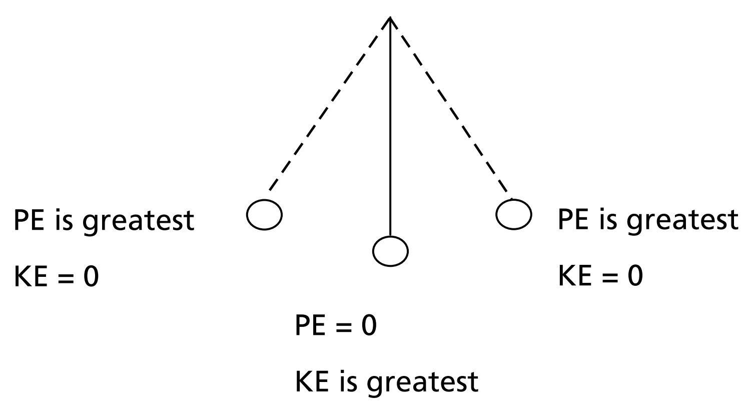
- ♦ To measure the motion and calculate the acceleration of a simple pendulum
- ♦ To understand the effect that gravity has on the motion of a pendulum

NSES Standards

- ♦ Physical Science: Force and motion

Preparation

- ♦ Students will use the CBL 2™ and a motion detector to measure the period of a simple pendulum. The resulting graph will provide them with the information they need to calculate the acceleration due to gravity on earth. As part of the introduction for this activity, it may help to explain why this works. Gravity causes the pendulum to accelerate after it is released and then causes it to slow down as it begins to rise again. This is also an excellent example of a transfer of energy from potential energy (PE) to kinetic energy (KE) and back to potential energy.



- The following formula applies for simple pendulums:

$$T = \frac{2\pi\sqrt{1}}{g}$$

- *T* is the period of the pendulum.
- *l* is the length of the pendulum from the pivot point to the center of the mass.
- *g* is the acceleration due to gravity.

Solving for *g* leads to the following formula, which is given at the start of the lab. Depending on your student's math level (algebra or pre-algebra), you may want to consider having them try to solve the above equation for *g* on their own as part of the introduction to the lab.

$$g = \frac{T^2}{4\pi^2 l}$$

- Place the ring stand near the edge of a table or other surface. Place a book or other object on the ring stand base to help keep it from falling off the table when the mass is attached. Attach a length of string (between 0.5 and 1.5 meters is recommended) to a mass large enough to be seen by the motion detector to the end of the string to make a simple pendulum.
- Set the motion detector on a chair or table top so that it is aimed at the mass at the end of the pendulum.

Application

You may want to have your students use the **Experimental Design** process to develop their own experiment. They will also need to design their own data collection table and figure out how to analyze the data they collect.

Management

- Assign these student jobs for this lab:
  - Materials/setup person (sets up samples, sensor)
  - Tech person (operates CBL 2™ and TI-73)
  - Data recorder (reads time readings from the TI-73 at each collection interval)
  - Runner (brings CBL 2 and TI-73 to the computer to print graphs with TI-GRAPH LINK™ or TI™ Connect and brings **Data Collection and Analysis** pages to the teacher)
- Clear covered plastic shoeboxes will hold a CBL 2, pH sensor, cups, rinsing bottle, and other equipment neatly at each station. If students are sharing one pH sensor, have representatives from each lab group bring test beverages in the cups to the sensor. Another option is to mount the sensor on a ring stand.

- Students can record time readings in their lab journals as they are displayed on the TI-73. This keeps them engaged throughout the data collection period and if they lose the data/graph later, they can still write up their lab reports. Students can also access the data in the TI-73 lists after data collection. You can send the lists to all students' calculators using [APPS] **1:Link**.

  a. Press [APPS].

  b. Press [ENTER] to select **1:Link.**

  c. Select **4:List** and press [ENTER].

  d. Press [▼] to move the ▸ beside the list you wish to send. Press [ENTER].

  e. Repeat step **d** for each list you wish to send.

  f. Set the receiving unit by pressing [APPS] [ENTER] [▶] to select **RECEIVE**. Press [ENTER]. **Waiting…** displays on the TI-73 screen.

  g. On the sending unit, press [▶] to select **TRANSMIT** and press [ENTER].

  For more permanent storage of data, use TI-GRAPH LINK™ or TI™ Connect to save the lists in a computer folder.

- Students can assess each other using a teamwork rubric after the lab. Provide a checklist of positive and negative behaviors. Copy these on quarter sheets of paper.