Bell Ringer: Pendulum Period and Length – ID: 13641

Based on an activity by Irina Lyublinskaya

Time required
15 minutes

Topic: Simple Harmonic Motion

- *Determine the period of an oscillating pendulum..*
- *Determine the equation relating a pendulum's period to its length.*

Activity Overview

In this activity, students analyze data from a swinging pendulum to determine the formula for the period of a pendulum using regression and dimensional analysis.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank sheet of paper*

TI-Nspire Applications

Graphs & Geometry, Lists & Spreadsheet, Data & Statistics, Notes, Calculator

Teacher Preparation

Before carrying out this activity, you should review with students the concepts of simple harmonic motion and the properties of a pendulum (mass, string length, and period).

- *The screenshots on pages 2–5 demonstrate expected student results. Refer to the screenshots on page 6 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains sample responses to the questions posed in the student .tns file.*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter "13641" in the search box.***
- *This activity is related to activity 12227: Pendulum Explorations. If you wish, you may extend this bell-ringer activity with the longer activity. You can download the files for activity 12227 at education.ti.com/exchange.*

Classroom Management

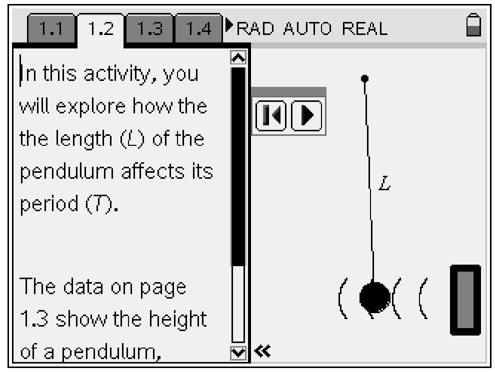
- *This activity is designed to be* ***teacher-led****, with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in* ***this*** *document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *If you wish, you may modify this document for use as a student instruction sheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*
- *If students do not have sufficient time to complete the main questions, they may also be completed as homework.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

The following questions will guide student exploration during this activity:

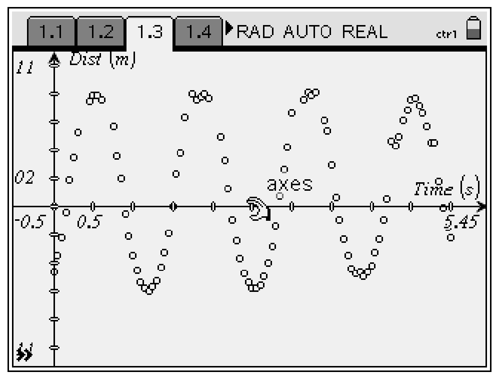
- What factors affect the period of pendulum oscillations?
- What is the equation for the period of pendulum oscillations?

The goal of this activity is for students to develop a mathematical model for the period of oscillations using experimental data and to use dimensional analysis to verify the mathematical model and derive a final equation for the period of a pendulum.

Step 1: Students should open the file **PhysBR_week22_pendulum.tns** and read the first two pages. Page 1.2 shows a simulation of a pendulum oscillating on a string with length *L*. Students should view the animation and then move to page 1.3. (To start the animation, students should move the NavPad to the ▸ button and press . To stop the animation, they should press again.)

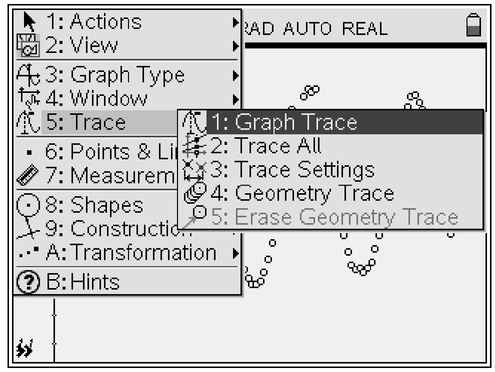


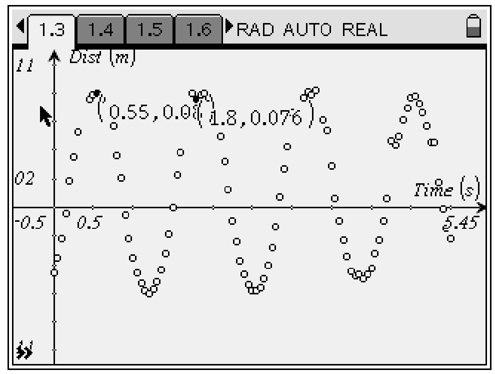
Step 2: Page 1.3 shows a graph of the height of a pendulum (represented by the variable *Dist*) as a function of time (represented by the variable *Time*). Students should study the graph and then answer question 1.



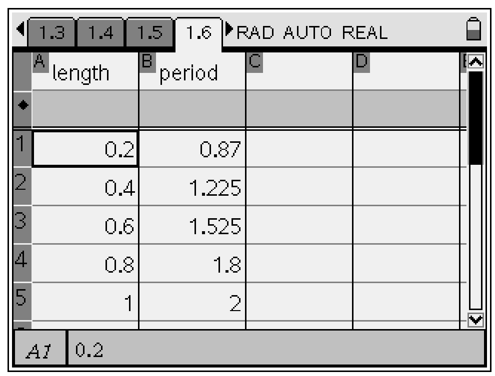
Q1. What is the period of the pendulum's oscillation on page 1.3?

A. *The period of the pendulum's oscillation is a measure of the time it takes the pendulum to complete one full oscillation. On the graph, this is the length of time between consecutive minima or maxima. To determine the x-coordinates of two maxima, students should use the* **Trace** *tool (***Menu > Trace > Graph Trace***). This tool confines the cursor to points along the graph. Students should press the ► and ◄ buttons to scroll between points. To obtain the coordinates of any data point, they can press . To calculate the period, students can subtract the values of consecutive x-coordinates. This value is approximately 1.25 s.*

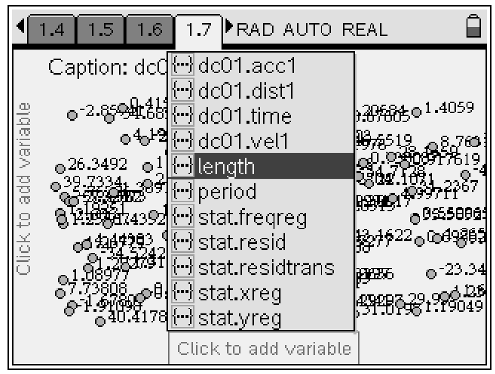


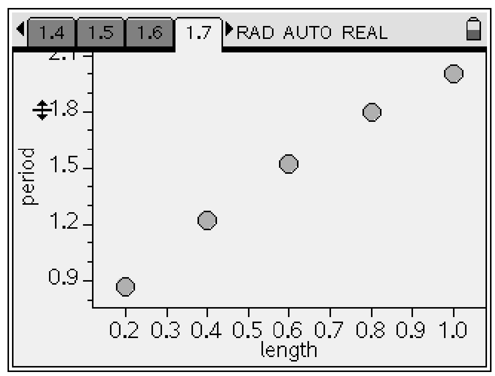


Step 3: Next, students should read page 1.5 and then move to page 1.6. The spreadsheet on page 1.6 contains the measured length and period of five different pendulums.



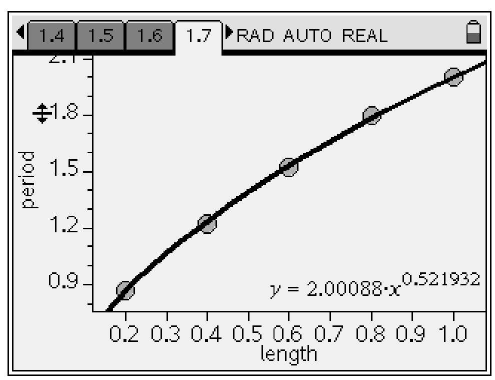
Step 4: Next, students should use the *Data & Statistics* application on page 1.7 to make a graph of period vs. length for the pendulum. They should use **length** as the *x*-axis variable and **period** as the *y*-axis variable. The scatter plot will display period as a function of length. To make the plot, they should use the NavPad to move the cursor to the *x*-axis. They should click once. A list of possible variables should pop up. They should use the NavPad to select **length** and then click once. They should then move the cursor to the *y*-axis, click, and choose **period** from the menu. Once both variables have been selected, the graph should appear. Once students have constructed the graph, they should answer questions 2–4.





Q2. Use the Power Regression tool to determine an equation for the plotted data on page 1.7.

A. *To use the **Power Regression** tool, students should return to page 1.7 and select **Menu > Analyze > Regression > Show Power**. This will show an equation with the form* $T = aL^{0.5}$*, where* T *is period,* a *is a constant, and* L *is length.*



Q3. Use dimensional analysis to determine the units of the constant in the equation from question 2. (Hint: express these units as a function of *g*, the acceleration due to gravity.)

A. *The dimensions of period are seconds (time), and the dimensions of length are meters (length). Plugging in these dimensions into the equation from question 2 yields*

$$time = a\sqrt{length}$$

$$a = \frac{time}{\sqrt{length}}$$

Note that the units of g *are m/s*^{2} *(length/time*^{2}*). The inverse square root of this,* $\sqrt{\frac{1}{g}}$ *, is* $\frac{time}{\sqrt{length}}$ *. Thus, the constant* a *from the equation in question 2 is a factor of* $\sqrt{\frac{1}{g}}$ *. The equation from question 2 can be rewritten as* $T = \frac{k}{\sqrt{g}}L^{0.5}$ *, where* k *is a constant.*

Q4. Determine the equation relating the period and length of a pendulum.

A. *The equation from question 3 equal and the equation determined using the power regression in question 2 take the same form. Setting the constants from these equations equal to each other gives the following:*

$$2.0 = \frac{k}{\sqrt{g}}$$

$$k = 2.0\sqrt{g}$$

$$k = 2.0\sqrt{9.8}$$

$$k = 6.3$$

Students may note that this constant is approximately 2π. Thus, the equation relating period and length of a pendulum can be written $T = 2\pi\sqrt{\frac{L}{g}}$.

Suggestions for Extension Activities: Have students solve for the period and length of a pendulum given different initial quantities. (For example, have students determine the period of a pendulum with a 3 m or 6 m string. Or, have students solve for the length of a pendulum with a 4 second period.) Also, students may want to calculate how the period is affected by doubling or tripling the length of the pendulum.

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(Student)TI-Nspire File: *PhysBR_week22_pendulum.tns*