Bell Ringer: Oscillations – ID: 13633

Based on an activity by Irina Lyublinskaya

Time required
15 minutes

Topic: Simple Harmonic Motion

- *Explore the motion of an oscillating spring.*
- *Determine an equation for the position and velocity of an oscillating spring system as a function of time.*

Activity Overview

In this activity, students explore the motion of a mass oscillating on a spring. Students then derive equations for the position and velocity of the mass as a function of time.

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 equation of motion for an oscillating mass (including a discussion of the amplitude, period, frequency, and phase of motion).

- *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 "13633" in the search box.***
- *This activity is related to activity 12192: Energy of Free Oscillations. If you wish, you may extend this bell-ringer activity with the longer activity. You can download the files for activity 12192 at education.ti.com/exchange.*

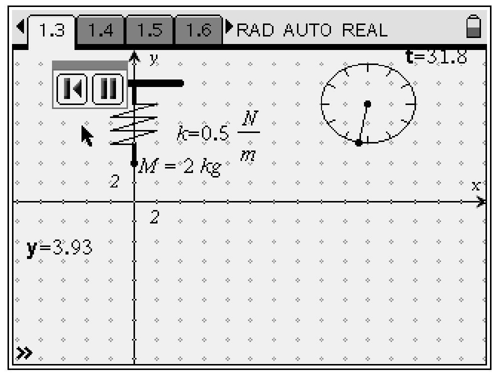
Classroom Management

- *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.*

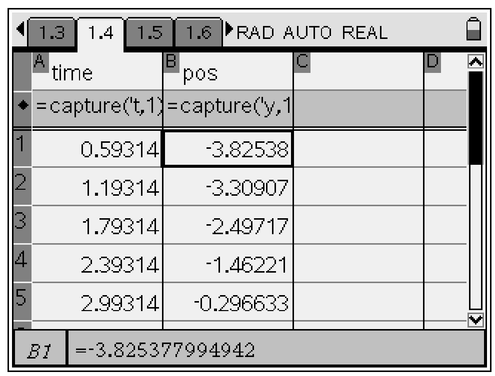
The following questions will guide student exploration during this activity:

- How can you describe the motion of an object in simply harmonic motion?
- What is the relationship between the position of an oscillating object and the velocity of the object?
- What is the amplitude of a mass oscillating on a spring?

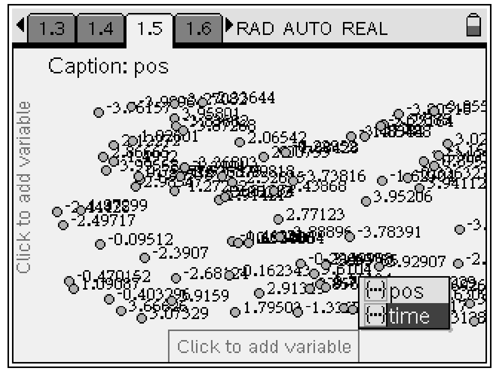
The purpose of this activity is to allow students to observe simulated spring–mass oscillations and collect data for the position and velocity of the oscillating mass. Then, students will graph the position and velocity of the oscillating mass as a function of time and derive equations for these variables.



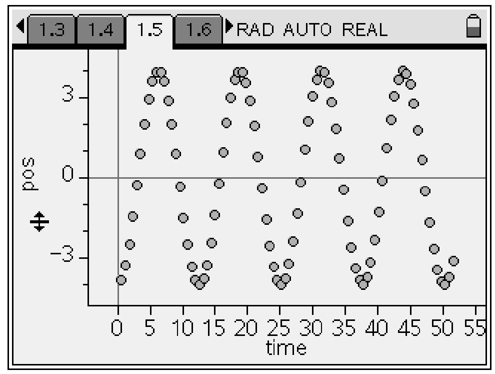
Step 1: Students should open the file **PhysBR_week21_oscillations.tns**, read the first two pages, and then move to page 1.3, which shows a 2-kg mass attached to a spring suspended vertically. The spring constant of the spring is 0.5 N/m. In this simulation, *t* represents the time in seconds and the clock measures up to 60 sec. The variable *y* represents the displacement of the mass from equilibrium, in meters. Students will use the animation to observe the changes in the position of the oscillating mass as time changes.



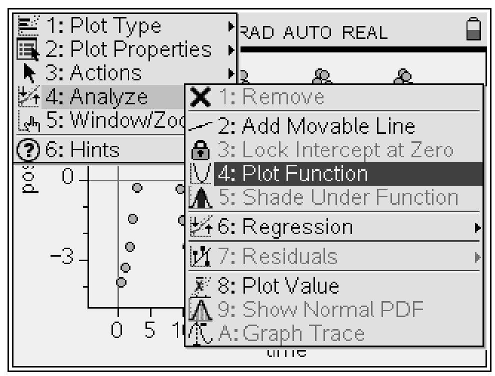
Step 2: Students should start the animation and allow it to run for 60 sec. (To start the animation, students should move the NavPad to the ▸ button and press the click button. To stop the animation, they should press the click button again.) The data for the position and time will be automatically captured in the *Lists & Spreadsheet* application on page 1.4.



Step 3: Next, students should use the *Data & Statistics* application on page 1.5 to make a graph of position vs. time for the mass. They should use **time** as the *x*-axis variable and **pos** as the *y*-axis variable. The scatter plot will display position as a function of time. 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 **time** and then click once. They should then move the cursor to the *y*-axis, click, and choose **pos** from the menu. Once both variables have been selected, the graph should appear.

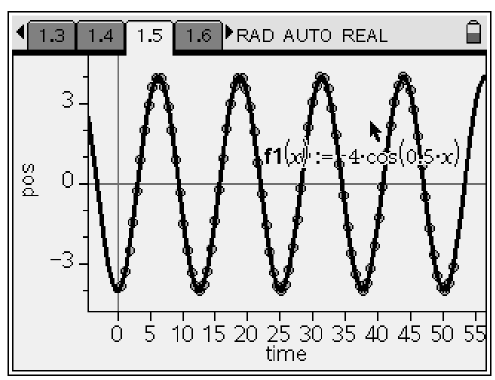


Step 4: Next, students should analyze the scatter plot and derive the equation for position as a function of time. Students can derive the equation in one of two ways. They can use the equation that describes the position of an oscillating mass and the information about the physical properties of the system (spring constant, mass, and initial displacement) to derive the equation. Or, they can use the properties of the data (amplitude, frequency, intersection points) to derive the equation mathematically. Either way, they should plot the function they derive on the graph and modify it if necessary until it fits the data. To do this, students should select **Menu > Analyze > Plot Function**. Then, they can enter the equation into the equation line. Then, they should answer question 1 on page 1.6.

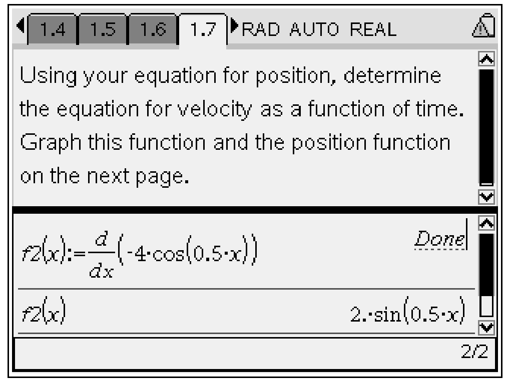


Q1. What is the equation describing the relationship between position and time?

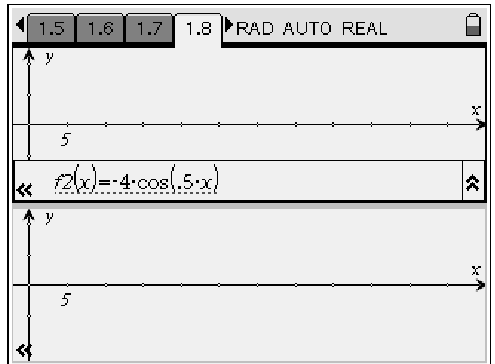
A. *The equation should be pos = –4·cos(0.5·time). Encourage students to discuss how they derived the equation from the properties of the system or the properties of the graph.*

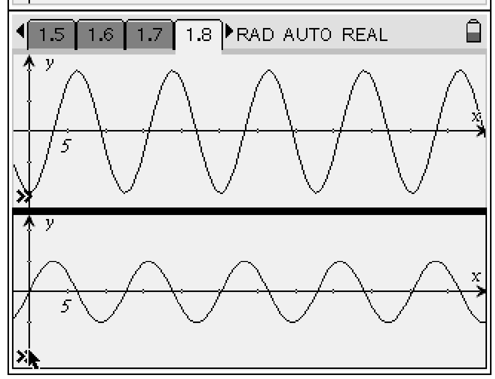


Step 5: Next, students should use the *Calculator* application on page 1.7 to determine the equation for velocity from the position equation. They should use the derivative template to determine the equation for velocity. (The derivative template can be accessed by pressing ctrl .) They should set this equation equal to **f2**(x). (The position equation should have been automatically assigned to function **f1**(x).) Students can press ctrl tab to move between applications. If students do not have TI-Nspire CAS technology, they should work the derivative by hand and then enter it onto the page.



Step 6: Next, students should move to page 1.8, which contains two *Graphs & Geometry* applications. They should graph position as a function of time, **f1**(x), on the top graph and velocity as a function of time, **f2**(x), on the bottom graph. To do this, students should move the NavPad to the function entry line and press . Then, they should enter the function. (If you wish, you may have students plot the derivative equation directly—i.e., plot the equation **f3**(x) = $2 \cdot \sin(0.5 \cdot x)$—instead of plotting **f2**.) Once students have graphed the two equations, they should answer questions 2 and 3.





Q2. What can you say about the velocity of the oscillating mass when it passes through the equilibrium position?

A. *The magnitude of velocity is maximum.*

Q3. What can you say about the position of the oscillating mass when its velocity is zero?

A. *The mass is displaced furthest from the equilibrium position.*

Q4. What is the angular frequency, frequency, and period of the mass on the spring?

A. *The angular frequency is defined as* $\omega = \sqrt{\frac{k}{m}}$ *, frequency is defined as* $f = \frac{\omega}{2\pi}$ *, and period is defined as* $T = \frac{1}{f}$ *. Thus, the angular frequency of the mass is 0.5 rad/s, frequency is 0.08 Hz, and period is 12.6 s.*

Q5. What is the acceleration of the mass on the spring? How can you express the acceleration of the mass as a function of its position?

A. *The acceleration of the mass is the derivative of the velocity function:*

$$a(t) = \frac{d}{dt}(v(t))$$

$$a(t) = \frac{d}{dt}(2sin(0.5t)$$

$$a(t) = cos(0.5t)$$

Note that the position function is: $y(t) = –4cos(0.5t)$ and $-\omega^2 = -0.25$. The product of these two terms gives the acceleration of the object:

$a(t) = (–4cos(0.5t))(–0.25) = cos(0.5t)$

Thus acceleration can be expressed as $a(t) = –\omega^2 y(t)$

Suggestions for Extension Activities: Have students answer questions 4 and 5 for systems consisting of different masses and springs with different spring constants. (Assume the spring is initially displaced the same amount that it is in the simulation on page 1.3.)

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(Student)TI-Nspire File: *PhysBR_week21_oscillations.tns*