



### Science Objectives

- Students will explore and compare the properties of standing waves and an electromagnetic wave.
- Students will observe different resonant frequencies of a standing wave on a spring.

### Vocabulary

- |                   |                             |
|-------------------|-----------------------------|
| • speed           | • damping                   |
| • amplitude       | • oscillation               |
| • resonance       | • standing wave             |
| • frequency       | • harmonics                 |
| • hertz           | • node                      |
| • period          | • anti-node                 |
| • spring constant | • electromagnetic radiation |

### About the Lesson




- In this lesson, students will:
  - Vary the frequency of a standing wave to observe different harmonics.
  - Relate higher resonant frequencies to the fundamental resonant frequency.
  - Compare the properties of standing waves and electromagnetic waves.

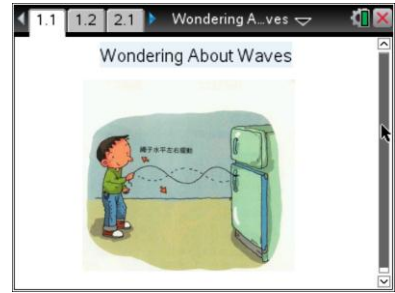


### TI-Nspire™ Navigator™

- Send out the *Wondering About Waves.tns* file.
- The questions are Self-Check which you might want to change to Exam.
- Monitor student progress using Class Capture.
- Use Student Live Presenter to spotlight student answers and presentation of solutions.

### Activity Materials

- Compatible TI Technologies:  TI-Nspire™ CX Handhelds,  TI-Nspire™ Apps for iPad®,  TI-Nspire™ Software



### Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at <http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials>

### Lesson Files:

- Wondering\_About\_Waves\_Teacher.doc
  - Wondering\_About\_Waves\_Student.doc
- TI-Nspire document*
- Wondering\_About\_Waves.tns



### Discussion Points and Possible Answers

Have students read the background information stated on their activity sheet or pages 1.2 - 1.3.

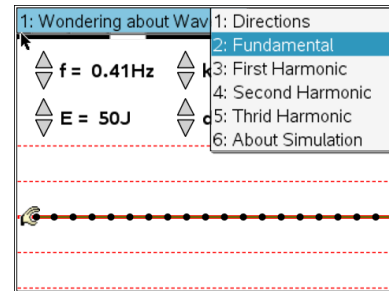
**Move to page 1.4 and answer the question below.**

Q1. A spring is fixed to the wall at one end. You are shaking the free end of a spring at different frequencies. How will you know when you are shaking the spring at a resonant frequency

**Sample Answer:** The amplitude of the wave is largest at the resonant frequencies. So, I will adjust the frequency until I notice that the wave has a large amplitude. This indicates it is oscillating at a resonant frequency.

**Move to page 1.5**


- Students will begin by observing the fundamental frequency of the spring. To do this, they should select **Menu > Wondering About Waves > Fundamental**. Then, they will select the play button to begin the simulation. Have students record the observed resonant frequency and energy of the spring in the table
- Students will use the up and down arrows (▼ and ▲) to set the energy to 20 J and observe what happens to the wave form. Then, they will use the up and down arrows to increase the frequency of the wave pulse. They should do this until they observe the second harmonic mode. Have students record the observed resonant frequency and energy in the table.
- Next, have students increase the energy to 100 J and increase the frequency until they observe the third harmonic mode. Have students record the observed resonant frequency and energy in the table.
- Have students increase the energy to 200 J and increase the frequency until they observe the fourth harmonic mode. They should record the observed resonant frequency and energy in the table.
- Finally, have students check their observed resonant frequencies with the actual resonant frequencies for each mode. To do this, have select **Menu > Wondering About Waves** and then select the second, third, and fourth harmonic modes. Students should observe the actual resonant frequencies and wave forms for each mode. They should record these frequencies in the table.





Harmonic Mode	Observed Resonant Frequency (Hz)	Energy (J)	Actual Resonant Frequency (Hz)
Fundamental	0.43	15	$f_1 = 0.43$
Second	0.83	20	$f_2 = 0.86$
Third	1.26	100	$f_3 = 1.29$
Fourth	1.55	200	$f_4 = 1.72$



**Tech Tip:** To access the Directions again, select  > **Wondering About Waves > Directions.**



**Tech Tip:** To access the Directions again, select  or **Document Tools** () > **Wondering About Waves > Directions.**

**Move to pages 1.6 - 1.10.**

Have students answer question 2-6 in the .tns file, the activity sheet, or both.

Q2. What happens when you increase the energy of the wave pulse in the simulation

**Answer:** C. The amplitude of the wave increases.

Q3. In which harmonic mode does the wavelength of the standing wave equal the length of the spring?

**Answer:** B. second harmonic

Q4. Observe the value of the actual fundamental resonant frequency,  $f_1$ . Compare this value to the other resonant frequencies by performing the following calculations:

**Answer:**

$$f_2 / f_1 = (0.86 \text{ Hz}) / (0.43 \text{ Hz}) = 2$$

$$f_3 / f_1 = (1.29 \text{ Hz}) / (0.43 \text{ Hz}) = 3$$

$$f_4 / f_1 = (1.72 \text{ Hz}) / (0.43 \text{ Hz}) = 4$$



**Tech Tip:** To insert a calculator press   and select **Calculator.**

Q5. Is there a pattern between higher harmonic frequencies and the fundamental frequency? Explain.



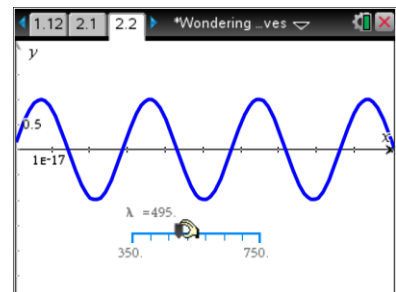
**Sample Answer:** Yes, the higher harmonics are multiples of the fundamental frequency. The second harmonic is twice the value of the fundamental, the third harmonic is three times the value of the fundamental, and the fourth harmonic is four times the value of the fundamental.

Q6. When you pluck a guitar string, you hear one note. This corresponds to the fundamental resonant frequency of the string. However, as you saw in this simulation, a string will resonant at many different frequencies. Why is it that you only hear one main frequency when you pluck a guitar string? (Hint: Return to the simulation and set the energy to 20 J. Then, observe the wave form at each of the different resonant frequencies. What do you notice about the amplitude of the higher harmonics?)

**Sample Answer:** The higher harmonics oscillate at much lower amplitudes than the fundamental. This means they have lower energy, and it would not be as easy to hear the sound they produce.

**Move to pages 2.1 – 2.2.**

6. Have students observe the simulation of the light wave on page 2.2. They should select and drag the slider to adjust the wavelength of the light and observe how the waveform changes.



**Move to page 2.3.**

Have students answer question 7 in the .tns file, the activity sheet, or both.

Q7. List two ways that the electromagnetic wave is different than the standing wave on the spring.

**Sample Answer:** The electromagnetic wave moves through space whereas the standing wave oscillates in one position; The electromagnetic wave oscillates fully at a continuous range of frequencies, whereas the standing wave only oscillates fully at specific resonant frequencies.



**TI-Nspire Navigator Opportunities**

Make a student a Live Presenter to show the waveform of a higher harmonic. .

Use Quick Poll as Formative Assessment.



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### Wrap Up

Students should compose a labeled poster showing the different waveforms corresponding to each harmonic. Students may choose to use the TI-Nspire™ Student Edition software to convert their .tns files to PublishView Documents.

### Assessment

- Use the questions in the Nspire document as Quick Polls during the lesson as needed.
- The questions in the Nspire document are Self-Check, so students can check their answers.
- Use Ranking Task as shown below.