Teacher Toolkit - Standing Waves on Strings

Objectives:

1. To describe how a standing wave is different than a traveling wave and to explain how a standing wave pattern on a string is formed from the interference of two waves.
2. To diagram the standing wave patterns for various *harmonics* of a vibrating string and to identify the harmonic number for each pattern.
3. To describe what nodes and antinodes are and to identify their location on a standing wave pattern.
4. To summarize the mathematical relationship between the wavelength and length of a string for various harmonics of a vibrating string.
5. To mathematically analyze a situation involving a standing wave in a guitar string to relate the harmonic number, string length, wavelength, frequency, and speed.

Readings:

The Physics Classroom Tutorial, Waves Chapter, Lesson 4
The Physics Classroom Tutorial, Sound Waves and Music Chapter, Lesson 5b

Interactive Simulations:

1. Standing Wave Maker http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Standing-Wave-Patterns
   The Standing Wave Maker allows learners to investigate the formation of standing waves, the vibrational patterns associated with the various harmonics, and the difference between transverse and longitudinal standing waves. This HTML5 simulation that excels at depicting the standing wave patterns for the various harmonics.
2. PhET - Waves on a String https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html
   This HTML5 simulation models the motion of a wave through a string by the up-and-down vibrations of a set of 60 inter-connected harmonic oscillators. Learners can manually vibrate the first oscillator or have the vibrations automated. The simulation can be viewed at normal speed or in slow motion.
3. A Standing Wave on a String http://physics.bu.edu/~duffy/HTML5/transverse_standing_wave.html
   This simulation shows the formation of a standing wave pattern by the interference of a rightward- and a leftward-moving wave. The standing wave pattern and the component waves are shown against the background grid that allows one to see the relative amplitude of the interfering wave and the resulting wave.
4. Standing Wave http://www.walter-fendt.de/html5/phen/standingwavereflection_en.htm
   This HTML5 simulation of a standing wave in a string depicts an incident wave, a reflected wave, and a standing wave formed in a string. Each wave is shown individually, beginning with the original incident wave. The end opposite the source can be fixed or free. Learners can select from among four different frequencies.

Video and Animation:

1. Hewitt Drewitt - Wave Interference https://www.youtube.com/watch?v=rXVHByK5Kmc
   This 8-minute video explains the phenomena of wave interference and the formation of standing waves. The principle of superposition, constructive and destructive interference, standing waves and standing wave patterns, guitar strings, and other sound- and music-related phenomenon are introduced and explained.
2. Standing Waves https://www.youtube.com/watch?v=jz8IIk_bps0
   Paul Andersen of Bozeman Science explains how standing waves are created through the reflection and interference of traveling waves. the 5-minute video provides a great overview of standing waves, their parts, and their formation. Basic terminology is introduced and explained and numerous illustrations are given.
3. The Physics of Playing Guitar http://ed.ted.com/lessons/the-physics-of-playing-guitar-oscar-fernando-perez
   This 5-minute TEDEd video explains the physics associated with guitars. The role of the sound box, the reason for varying string thickness, the role of frets and the reason for their spacing distance, and the connection between guitars and other stringed instruments is discussed.
4. Standing Wave Animation https://www.desmos.com/calculator/65ycbghqli
   This Desmos Graphing file is set to animate a standing wave by scrolling a parameter value between a pre-set minimum and maximum value. Physics teachers will find it helpful for demonstrating how a standing wave is formed by the superposition of two interfering waves.

Labs and Investigations: **From The Physics Classroom, The Laboratory**

1. Harmonic Frequencies Lab http://www.physicsclassroom.com/lab/waves/Wlabs.html
2. Guitar String Lab http://www.physicsclassroom.com/lab/sound/Slabs.html

Demonstration Ideas:

1. Gum Drop Wave Machine https://www.youtube.com/watch?v=cWcrOW-mlwY
   With some duct tape, $2 worth of candy, and some skewer sticks from the local party store, you can make a real "sweet-looking" wave machine. Shake it at just the right frequency and you can get it to vibrate with one of its harmonic patterns. This slow-motion video shows the end product in action.
2. Wave Reflection and Standing Waves https://www.youtube.com/watch?v=-n1d1rycvj4
   James Lincoln of UCLA Physics Videos uses a snakey to demonstrate how reflected waves at a fixed end can interfere with incident waves from a source to produce a standing wave interference pattern. The demonstrations shown in this short 45-second video can easily be repeated live before students.

Minds On Physics Internet Modules: http://www.physicsclassroom.com/mop

Minds On Physics is a collection of interactive questioning modules targeting student's conceptual understanding. Each question is accompanied by detailed help that addresses the various components of the question.

1. Wave Motion, Ass't WM7 - Mathematics of Standing Waves 1
2. Wave Motion, Ass't WM8 - Mathematics of Standing Waves 2
3. Sound and Music, Ass't SM6 - Harmonics of Stringed Instruments
4. Sound and Music, Ass't SM7 - Mathematics of Stringed Instruments

Concept Building Exercises: **From The Curriculum Corner**

1. Wave Basics, Standing Wave Mathematics http://www.physicsclassroom.com/curriculum/waves
2. Sound and Music, Resonance http://www.physicsclassroom.com/curriculum/sound
3. Sound and Music, Resonance and Guitar Strings http://www.physicsclassroom.com/curriculum/sound

Problem-Solving Exercises **From The Calculator Pad**

1. Wave Basics, Problems #18 - #27 http://www.physicsclassroom.com/calcpad/waves/problems
2. Sound and Music, Problems #14 - #20 http://www.physicsclassroom.com/calcpad/sound/problems

Science Reasoning Activities

1. Standing Waves on a Rope http://www.physicsclassroom.com/reasoning/waves

Common Misconceptions **See Website for Complete Details**

1. Antinodes, Crests, and Troughs
2. Identifying a Wavelength on a Standing Wave Pattern

Standards:

A. Next Generation Science Standards (NGSS) – Grades 9-12

Disciplinary Core Ideas - Waves and Their Applications (HS-PS4-1)

Crosscutting Concepts

- **Patterns:**
- **Scale, Proportion and Quantity:**
- **Systems and System Models:**

Science and Engineering Practices

- **Practice #2: Developing and Using Models**
- **Practice #3: Planning and Carrying Out Investigations**
- **Practice #5: Using Mathematics and Computational Thinking**
- **Practice #7: Engaging in Argument from Evidence**

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