Teacher Toolkit - Behavior of Waves

Objectives:

1. Predict how alterations in the medium through which a wave is traveling will affect the properties of that wave such as wavelength and speed.
2. Predict the orientation of the reflected pulse at the boundary between two media and at a free-end and a fixed-end.
3. Recognize the distinction between constructive and destructive interference and to use the principle of superposition to construct the resultant waveform from the two interfering waves.
4. Describe the Doppler effect phenomenon and to explain its cause using words, diagrams, and formulas.
5. Describe the phenomenon of wave reflection, refraction, and diffraction; to explain when each of these variables occur and to discuss the variables that affect the degree to which they occur.

Readings: The Physics Classroom Tutorial, Waves Chapter, Lesson 3

Interactive Simulations:

1. Slinky Interactive http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Slinky-Lab
   Our mobile-friendly Slinky simulation offers a host of ways to explore vibrations and wave behavior. Use the interactive tools to investigate how frequency, tension, and density affect the vibrational motion of particles and the speed of a transverse wave as it moves through a medium. Accompanied by a classroom-ready student exercise.
2. Interactive Waves Tutorial http://www.compadre.org/books/?ID=15
   This set of 33 simulation-based interactive tutorials was designed to teach the fundamentals of waves. Topics include wave superposition, interference, Fourier analysis, boundary behavior, impedance, diffraction, Doppler Effect, and more. **Teachers:** The entire collection is available in ready-to-run HTML5 format, with question sets for each activity.
3. PhET: Wave on a String https://phet.colorado.edu/en/simulation/wave-on-a-string
   This HTML5 activity simulates the motion of a vibrating string. Students can generate pulses manually or click "Oscillator" and let the simulation create traveling or standing waves. The string is modeled as a series of interacting masses. The tension of the string, damping, and frequency and amplitude of the oscillator can be adjusted.
4. Wave Machine Model http://www.thephysicsfront.org/items/detail.cfm?ID=10481
   This Java simulation from Open Source Physics, coupled with historic 1959 video of John Shive demonstrating his iconic wave-generating machine. The model was constructed to simulate Shive's wave machine, consisting of horizontal cross-bars welded to a central wire spine perpendicular to the bars.

Video and Animation:

1. Direct Measurement Video: Wave Superposition http://serc.carleton.edu/dmvideos/videos/wave_superposit.html
   What happens when two waves overlap in the same medium? Do they reflect off each other or pass through each other? Do they add or subtract? These high-resolution videos allow students to make observations to explore the conditions that govern wave superposition.
2. Direct Measurement Video: Wave Reflection http://serc.carleton.edu/dmvideos/videos/wave_reflection.html
   How do waves reflect from barriers? This resource provides high-resolution videos of waves reflecting from both fixed and free ends. The slow-motion feature allows students to see how a wave is affected by either type of reflection. Vertical and horizontal measurement tools are also provided to allow calculation.
3. Similarities of Wave Behavior http://techchannel.att.com/play-video.cfm/2011/3/7/AT&T-Archives-Similarities-of-Wave-Behavior
   This historic 1959 video shows physicist John Shive demonstrating his iconic Wave Machine, a system consisting of horizontal cross-bars welded to a central wire spine. It's not just the ingenious model we like, it's Dr. Shive's great way of explaining how "waves of all kinds behave fundamentally alike".
4. Wave Adder http://zonalandeducation.com/mstm/physics/waves/waveAdder/WaveAdder1.html
   This animated activity lets students explore wave interference interactively as they set values for amplitude, frequency, and phase shift to draw two waves. Click "Add Yellow to White" to see the sum of the waves that have been added.
5. Standing Waves on a String http://demoweb.physics.ucla.edu/content/standing-waves-string
   Join physics teacher James Lincoln as he puts on a very visual display to demonstrate that standing waves really aren't "standing" at all. Using fluorescence and strobe lights with a standing wave maker machine, Lincoln takes you from 1st through 5th harmonics to show the nature of nodes and antinodes.

Physics Education Research http://www.physics.umd.edu/perg/papers/wittmann/seminartalk/index.htm

1. Student Difficulties with Wave Concepts, by Michael C. Wittman
   This presentation by Michael Wittman of the Physics Education Research Laboratory shows results of a research study on misconceptions held by students about wave mechanics and motion. The results indicate that many students have incorrect mental models of waves and use these erroneous models to interpret problems related to wave mechanics.

Labs and Investigations: **See Complete Toolkit on Website for More Details**

1. Wave Behavior Demonstration Lab http://www.physicsclassroom.com/lab#waves
2. Ripples Crossing-Interference http://practicalphysics.org/ripples-crossing-interference.html

Demonstrations and Elicitation:

1. Wave Machine Demonstration https://www.youtube.com/watch?v=VE520z_ugcU
   Want to build your own wave machine? This cool video, produced by the UK's National STEM Centre, shows how to do exactly that with gummi candies, duct tape, and kabob sticks. It might not rival the Shive Wave Machine, but it could be a really useful tool to demonstrate wave behavior in your classroom.
2. Wave Clicker Questions https://phet.colorado.edu/en/contributions/view/3032
   An exemplary set of 60+ clicker questions (with answer key) for use in a Wave Unit for introductory physics. It was authored by a veteran HS physics teacher to accompany PhET simulations related to wave behavior.
3. Light Wave Diffraction http://demoweb.physics.ucla.edu/content/light-wave-diffraction
   James Lincoln uses a wave tank system that reflects illuminated plane waves onto a projection screen. You can see the plane waves before they diffract, then watch their boundary behavior with a double-slit barrier (they diffract).

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

The Minds On Physics Internet Modules are a collection of interactive questioning modules that target a student's conceptual understanding. Each question is accompanied by help that addresses the various components of the question.

1. Wave Motion, Ass't WM5 - Boundary Behavior of Waves
2. Wave Motion, Ass't WM6 - Interference of Waves
3. Sound and Music, Ass't SM4 - The Doppler Effect

Concept Building Exercises http://www.physicsclassroom.com/curriculum/

1. The Curriculum Corner, Wave Basics, Boundary Behavior of Waves
2. The Curriculum Corner, Wave Basics, Interference of Waves
3. The Curriculum Corner, Sound and Music, The Doppler Effect

Real Life Connections: **See Complete Toolkit on Website for More Details**

Red Shift and Doppler Effect https://www.youtube.com/watch?v=y5tKC3nEx2I

Content Support for Teachers **See Complete Toolkit on Website for More Details**

Light and Matter: Vibrations and Waves

Common Misconceptions **See Complete Toolkit on Website for More Details**

The Meeting of Waves

Standards - Next Generation Science Standards (NGSS): **See Complete Toolkit on Website for More Details**

Performance Expectation: High School Physical Science - Waves HS-PS4-1
Disciplinary Core Ideas: Wave Properties: HS-PS4.A.iii:
Crosscutting Concepts: Patterns
Science and Engineering Practices
Practice #1: Analyzing and Interpreting Data
Practice #3: Constructing Explanations
Practice #4: Developing and Using Models
Practice #8: Using Mathematics and Computational Thinking