Teacher Toolkit - Resonance and Air Columns

Objectives:

1. To describe how one object that vibrates at the same natural frequency of another object can force that second object into resonant vibrations and to identify and discuss several examples of such resonance phenomenon.
2. To associate a resonating object with a standing wave pattern and to examine such patterns and identify their nodes and antinodes.
3. To define fundamental frequency and to mathematically relate the fundamental frequency to the frequency of the various harmonics of a vibrating object.
4. To draw the standing wave patterns for the various harmonics of an open-end and a closed-end air column and to relate the length of the column to the wavelength of the standing wave patterns.
5. To use the speed-wavelength-frequency relation to analyze a standing wave situation and relate the frequency of the harmonic to the length of the air column and the speed of sound waves within the air column.

Readings:

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

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

Interactive Simulations:

1. Standing Wave Maker http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Standing-Wave-Patterns
   The Standing Wave Maker at The Physics Classroom models both the transverse wave motion and the longitudinal wave motion (select Show Wave as Sound). Learners can explore by building a Custom Wave or selecting from among the Pre-Set Waves.
2. Measuring the Speed of Sound http://physics.bu.edu/~duffy/HTML5/speed_of_sound.html
   This simulation resembles the resonance tube lab often used to determine the speed of sound. The simulation would make an excellent pre-cursor to such a hands-on experience or would serve as a stand-alone activity.
3. Longitudinal Standing Wave http://physics.bu.edu/~duffy/HTML5/longitudinal_standing_wave.html
   This simulation shows the vibrational motion of the air particles for a longitudinal standing wave in an air column. The motion of both the rightward- and the leftward-moving waves are shown along with the superposition of these motions and a transverse representation of the standing wave.
4. Forced Oscillations and Resonance http://www.walter-fendt.de/html5/phen/resonance_en.htm
   This resonance simulation allows students to adjust the frequency of a forced vibration until it matches the natural frequency of a vibrating spring. Once there is a match, resonance occurs.
5. Standing Longitudinal Wave http://www.walter-fendt.de/html5/phen/standinglongitudinalwaves_en.htm
   This HTML5 simulation show the various harmonics produced in an open- and a closed-end air column. The standing wave patterns are shown and the nodal and antinodal positions are marked. The back-and-forth vibration of the particles along the column are shown. Buttons allow one to change the harmonic.

Video and Animation:

1. Resonance of Sound https://www.youtube.com/watch?v=7bx3xx7sB0c
   Physics Professor Paul Hewitt explains the concepts of natural frequency, harmonics, and resonance. Numerous illustrations and examples of resonance are given.
2. Standing Sound Waves https://www.youtube.com/watch?v=bHdHaYNX4Tk
   James Lincoln of AAPT Films provides numerous ideas for demonstrations and instruction on the topic of standing waves produced by interfering sound waves. Each demonstration is described and the physics principles are explained.
3. Standing Waves and Resonance https://www.youtube.com/watch?v=VBssGPfYBr4
   This series of three consecutive animations demonstrates resonance in a closed-end air column. The vibrations of a tuning fork forces air inside a closed-end air column into vibration. A plot of the intensity of sound as a function of the length of the air column is shown as a piston is slowly moved along the air column.
4. The Collapse of the Tacoma Narrows Bridge https://www.youtube.com/watch?v=KqqyAZDpV6c
   This 10-minute video from the Washington History YouTube channel provides great historical and scientific detail regarding the construction and collapse of the Tacoma Narrows bridge. The video discusses the role of resonance in the collapse and explains the impact upon subsequent suspension bridge construction.
5. Resonant Experiment https://www.youtube.com/watch?v=JDnNmLkQ3Bc
   This three-minute YouTube video features David Goodstein from the Mechanical Universe series explaining and demonstrating the method of breaking a wine glass (or beaker) using resonance.

Labs and Investigations:

1. The Physics Classroom, The Laboratory, Vibrating Spring Lab
2. The Physics Classroom, The Laboratory, Nodes and Antinodes Lab
   Link: http://www.physicsclassroom.com/lab/waves/Wlabs.cfm
3. The Physics Classroom, The Laboratory, Closed End Air Column Lab
4. The Physics Classroom, The Laboratory, Open-End Air Column Lab
   Link: http://www.physicsclassroom.com/lab/sound/Slabs.cfm

Demonstration Ideas:

1. Inverted Pendulum Demonstration https://www.youtube.com/watch?v=tnS0SYF4pYE
   Using a commerical model, The Physics Classroom author quickly demonstrates the concepts of natural frequency, force vibration, and resonance.
2. Water Goblet Resonance https://www.youtube.com/watch?v=X5Uy7MhFiWA
   A water goblet is forced to vibrate by running a finger over its rim. The stick-slip friction between the finger and the glass causes the glass to resonate in sync with the slipping and sticking of the finger.
3. Longitudinal Standing Wave in a Spring https://www.youtube.com/watch?v=12pjjPIE2IQ
   If you have access to a frequency generator and mechanical oscillator, you can set up this demonstration quite quickly. The nearly 3.5-minute describes how to use a vibrating spring to study longitudinal standing waves.
4. Chladni Plates with The Physics Girl https://www.youtube.com/watch?v=wYoxOJDrZzw
   If you have a frequency generator and a Chladni plate, you can perform this demonstration live for your students. They will not forget it. The Physics Girl does the demonstration and thoroughly explains how it works with her usual excitement and accuracy.

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 detailed help that addresses the various components of the question.

1. Sound and Music, Ass't SM5 - Resonance and Standing Wave Patterns
2. Sound and Music, Ass't SM8 - Harmonics for Open-End Air Columns
3. Sound and Music, Ass't SM9 - Mathematics for Open-End Air Columns
4. Sound and Music, Ass't SM10 - Harmonics for Closed-End Air Columns
5. Sound and Music, Ass't SM11 - Mathematics for Closed -End Air Columns

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

1. The Curriculum Corner, Sound and Music, Resonance
2. The Curriculum Corner, Sound and Music, Resonance and Open-End Air Columns
3. The Curriculum Corner, Sound and Music, Resonance and Closed-End Air Columns

Problem-Solving Exercises: http://www.physicsclassroom.com/calcpad/sound

1. The Calculator Pad, Sound and Music, Problems #21 - #31

Science Reasoning Activities: http://www.physicsclassroom.com/reasoning/sound

1. The Sound of Music

Cool Stuff Worth Showing **See Complete Toolkit on Website for Details**

1. Chladni Patterns http://www.itsokaytobesmart.com/post/27927640271/chladni-patterns-acoustic-science

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

1. Physics and Acoustics of Baseball and Softball Bats http://www.acs.psu.edu/drussell/bats.html

Standards:

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

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

Crosscutting Concepts: Patterns; Cause and Effect; Scale, Proportion, and Quantity; Systems and System Models

Science and Engineering Practices: Practice #2, #3, #5, and #7