Teacher Toolkit – Describing Waves

Objectives:

1. Describe the nature of a wave as a disturbance that moves through a medium, transporting energy without transporting matter.
2. Distinguish local particle vibrations from overall wave motion and relate these distinctions to types of waves such as longitudinal, transverse and surface waves.
3. Demonstrate understanding of wave properties such as wavelength, amplitude, frequency, period, and speed and mathematically relate these properties to one another.
4. Apply the relationship among wave speed, frequency, and wavelength to solve problems.
5. Build understanding of the relationship between energy and amplitude.

Readings: The Physics Classroom Tutorial, Waves Chapter, Lesson 1 and 2

Interactive Simulations:

1. PhET Simulation: Wave on a String http://phet.colorado.edu/en/simulation/wave-on-a-string
   Wiggle the string to create a wave. Set frequency, amplitude, and tension and watch the results…..or manually generate the disturbance. You can choose fixed, loose, or no end.
2. Wave Representations Model http://www.opensourcephysics.org/items/detail.cfm?ID=7618
   A flexible model that displays motion of a wave on a string alongside Displacement/Time graph for two points on the string. Using these representations, you can determine amplitude, period, wavelength, and wave speed.
3. PhET Simulation: Fourier-Making Waves http://phet.colorado.edu/en/simulation/fourier
   Advanced simulation lets learners create different kinds of waves by adding sines or cosines. Developed to help students become comfortable with mathematical expressions for waves. (Great resource for gifted/talented.)

Video and Animation:

1. Longitudinal/Transverse Wave Motion http://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html
   Simple, yet very effective way to visualize the motion of four types of waves: longitudinal, transverse, water, and Rayleigh surface waves. Clearly shows how the wave motion is not the same as the motion of particles.
2. LivePhoto Physics: Wave Pulse Propagation on a Slinky Spring http://livephoto.rit.edu/LPVideos/Slinky/
   Short video clips of wave pulses on a slinky spring, shot with high-speed camera for frame-by-frame stepping. Collect position and time date with free Tracker Video Analysis tool: www.cabrillo.edu/~dbrown/tracker/
3. Internet Archive: Tacoma Narrows Bridge Collapse https://archive.org/details/SF121
   Dramatic 2.5-minute original footage of the 1940 collapse of the Tacoma Narrows Bridge in Washington. Winds gusting at 42 mph drove the span into large-amplitude oscillatory motion.

Labs and Investigations:

1. The Physics Classroom, The Laboratory, A Wiggle in Time http://www.physicsclassroom.com/lab#waves
   Students observe and describe the motion of a mass on the end of a spring. Using a motion detector, they describe the motion with words, with graphs, and in mathematical terms.
2. The Physics Classroom, The Laboratory, A Wiggle in Time and Space http://www.physicsclassroom.com/lab#waves
   Students explore the connection between a mass vibrating on a spring and a collection of particles vibrating back and forth about a fixed position along the medium as a wave passes through the medium.
3. The Physics Classroom, The Laboratory, Wave Motion http://www.physicsclassroom.com/lab#waves
   Students observe simulations and observe the difference between longitudinal, transverse and surface waves.
4. The Physics Classroom, The Laboratory, Speed of a Wave http://www.physicsclassroom.com/lab#waves
   Students investigate the variables that do and do not affect the speed of a wave.

Demonstration Ideas:

1. Waves With Trolleys http://www.nuffieldfoundation.org/practical-physics/waves-trolleys
   Highly visual demo uses dynamics trolleys, springs, and spring holders to model transverse and longitudinal waves. Easy set-up, yet allows exploration of complex concepts such as how a dispersive system differs from a continuous wave medium like a rope or slinky. Developed by Practical Physics.
2. Wave Motion Machine http://techchannel.att.com/play-video.cfm/2011/3/7/AT&T-Archives-Similarities-of-Wave-Behavior
   An oldie but goodie….this 28-minute historic film features physicist John Shive demonstrating his torsional "wave machine" at Bell labs. Watch wave reflection from fixed and free ends, wave superposition, standing waves, and wave impedance. If time is limited, start the video at 6 minutes and watch to 11 minutes. Students can see the real-life wave motion and compare it to the simulations.

This is the *To Go* version of the Teacher Toolkit; it is an abbreviated version of the online Toolkit.

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

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

1. Waves module, Assignment WM1 – Nature and Categories of Waves
2. Waves module, Assignment WM2 – Wave Characteristics
3. Waves module, Assignment WM3 – Speed of a Wave

Conceptual Building Exercises:

The Physics Classroom, Curriculum Corner, Wave Basics http://www.physicsclassroom.com/curriculum/waves

1. Waves 2. Describing Waves 3. Wave Speed

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

1. The Physics Classroom, The Calculator Pad, Wave Basics, Problems #1-17

Science Reasoning Activity: http://www.physicsclassroom.com/reasoning/waves

1. The Physics Classroom, Science Reasoning Center, Waves: Mass on a Spring

Real Life Connections:

1. Modeling the 2004 Indian Ocean Tsunami for Introductory Physics Students
   http://www.jcu.edu/educatio/greg/Research/Tsunami/Tsunami_article.pdf
   A "how-to" article on building a simple tank to model the motion of a tsunami wave, plus explicit instructions on how to create an impulsive disturbance in the tank to simulate an earthquake that will, in turn, generate a tsunami-like wave in the 6-foot trough.

Common Misconceptions

1. What Moves?
   It is common for students to believe that waves involve the transport of matter from the source to a distant location. Emphasize that waves do not transport matter. What one sees as a wave moves through a Slinky™ or water is the movement of a pattern of crests and troughs (or compressions and rarefactions); this results in the movement of energy without any movement of matter. Particles within the medium (i.e., matter) simple vibrate back-and-forth about a fixed position.
2. Confusion of Frequency and Speed
   Students often confuse the concepts of wave frequency and wave speed. Wave speed refers to how fast a wave moves and is related to the distance traveled by a point on a wave per unit of time. Speed is much different than frequency. Frequency describes how often particles of the medium undergo vibrations about their fixed position. A medium in which particles vibrate frequently about a fixed position is not necessarily a fast wave. Be cautious of your own use of the terms frequency and speed and monitor the language of students and gently correct those who describe frequent vibrations as fast.

Elsewhere on the Web:

Student Difficulties with Wave Concepts http://www.physics.umd.edu/perg/papers/wittmann/seminartalk/index.htm

A must-read 44-slide PowerPoint presentation by Michael Wittmann, physics professor and team member of the University of Maryland PER (Physics Education Research Group). See the results of research on how students formulate mental models of waves concepts and learn to recognize common misconceptions.

Standards

A. **Next Generation Science Standards (NGSS) – Grades 9-12**
   Disciplinary Core Ideas: High School-PS4.A.i, High School-PS4.A.iii , Middle School-PS4.A.i
   Performance Expectations: Middle School PS4-1, Middle School PS4-2, High School PS4-1
   Science and Engineering Practices: #1, #3, #4, #5, #6, and #8
B. **Common Core Standards (CC) – Grades 9-12 Mathematics**
   Standards for Mathematical Practice: Reason abstractly and quantitatively; Model with mathematics
   Other high school standards: **N-Q.1**, **A-SSE.2**, **A-REI.10**, **F-IF.5**, **F-IF.6**, **F-IF.9**, **F-TF.5**, and **F-TF.7**
C. **Common Core Standards (CC) – Grades 9-12 English/Language Arts**
   High School – Reading Standards for Literacy in Science and Technical Subjects: **RST.11-12.2**, **RST.11-12.4**, **RST.11.12.7**, **RST.11-12.9**, **RST.9-12.10**
D. **College Ready Physics Standards (Heller and Stewart)**
   Objective 4.3 Mechanical Wave Interactions and Energy