Teacher Toolkit - Wave Model of Light

Objectives:

1. To understand the historical debate surrounding the nature of light as a wave and as a particle and to identify a few pieces of evidence in support of each model.
2. To describe the distinction between non-polarized and polarized light and to use a wave model to explain how polarization occurs and how a Polaroid filter works to polarize light.
3. To identify the regions of the electromagnetic spectrum and to compare the relative wavelength, frequency, and energy of these various wave types; to describe the relative hazard that waves within each region pose to human beings.
4. To use a wave model to explain how a two-point source interference pattern is created.
5. To use Young's equation and experimental data to determine the wavelength of laser light.

Readings:

The Physics Classroom Tutorial, Light and Color Chapter, Lesson 3

Interactive Simulations:

1. Young's Experiment http://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Youngs-Experiment
   This interactive from The Physics Classroom simulates a Young's Experiment set-up using laser light shining upon a double slit. Students make measurements of the slit separation distance, the slit-to-screen distance, and the band separation distance on the screen.
2. Waves: An Interactive Tutorial http://www.compadre.org/books/?ID=15
   Using 33 interactive simulations, this exemplary eBook explores the physics of waves. The simulations are ready to run on mobile devices and include question sets to gauge student understanding.
3. Electromagnetic Spectrum http://earthguide.ucsd.edu/eoc/special_topics/teach/sp_climate_change/p_emspectrum_interactive.html
   Students will have fun exploring the EM Spectrum with this interactive tool. Move the slider to investigate the differences among the seven types of electromagnetic radiation. Values for wavelength in meters, frequency in Hertz, and energy in energy volts are given, along with conceptual representations of energy and frequency.
4. Polarizer http://www.thelearningodyssey.com/Graphics/Content/vs/em/Medias/html/a454-polarizer.html
   This simulation lets students shoot a beam of light through two polarizers. Starting with an elliptically polarized beam, the polarizer transforms this incident beam into a linearly polarized one. Use the slider to change the orientation of the second polarizer.

Video and Animation:

1. Veritasium: The Original Double Slit Experiment https://www.youtube.com/watch?v=Iuv6hY6zsd0
   Dr. Muller uses a mini-refrigerator box, a commercial double-slit slide, and an eyepiece for viewing the pattern in the dark box. He takes the homemade apparatus out in bright sunlight and asks volunteers for predictions of what they would see.
2. STEM Learning Centre: Diffraction of Laser Light https://www.stem.org.uk/elibrary/resource/26770
   This superb resource from the UK's Institute of Physics features two videos – one for teachers and a second aimed at students.
3. Polarization of Light https://www.youtube.com/watch?v=E9qpbt0v5Hw
   Physics teacher James Lincoln explains linear polarization of light in a 2-minute video. Lincoln does a macro-scale demonstration to show how we know that light is a transverse wave. He then uses polarized light filters to show how the concept shown in the demo can be extended to light phenomena.
4. Tout Est Quantique: Wave Particle Duality http://toutestquantique.fr/en/duality/
   This animation depicts a double-slit set-up with a light source, a plate pierced by two parallel slits, and a screen where light passing through the slits is observed. It shows three objects being fired through the slits: single particles, waves, and a "quantum object".
5. Tout Est Quantique: Polarizing Microscope http://toutestquantique.fr/en/polarizing/
   This animation from Physics Reimagined shows what happens when a birefringent sample is positioned along a light beam with two perpendicular filters. Normally, no wave could pass through such a set-up. But birefringent materials produce a "double refraction" phenomenon that splits the light into two rays!

Labs and Investigations: http://www.physicsclassroom.com/lab/light/Llabs.html

1. The Physics Classroom, The Laboratory, Ripple Tank Lab
2. The Physics Classroom, The Laboratory, Two-Point Source Analysis
3. The Physics Classroom, The Laboratory, Young's Experiment Lab
4. The Physics Classroom, The Laboratory, Getting It Right with Light

Hands-On Investigations:

1. Teaching Advanced Physics (TAP): Polarisation http://tap.iop.org/vibration/em/313/page_46681.html
   This lesson module promotes active learning about concepts of polarization and how it is applied in wave technology. It includes opening discussion tips, high-quality diagrams for full-class projection, complete procedurals for setting up two class demonstrations, a lab experiment to investigate radio and TV signals, and a robust problem set with answer key.

Historical Context: **See the Complete Toolkit on our Website for Details.**

1. Microscopy U: Principles of Interference
   http://www.microscopyu.com/techniques/polarized-light/principles-of-interference
2. Microscopy Resource Center: Light – Particle or a Wave?
   http://www.olympusmicro.com/primer/lightandcolor/particleorwave.html

Classroom Presentation Materials:

1. U.S. Department of Energy: Ionizing Radiation http://energy.gov/ne/downloads/lesson-4-ionizing-radiation
   This annotated Power Point presentation developed by the DOE takes a deep look at the energy spectrum of radiation, from low-frequency non-ionizing radiation to the higher-frequency ionizing radiation that can damage living cells.

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

Minds On Physics is a collection of interactive questioning modules that target a student's conceptual understanding and utilize detailed help that address the various components of the question.

1. Light and Color to, Ass't LC1 - Electromagnetic and Visible Radiation
2. Light and Color Module, Ass't LC2 - Polarization

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

1. The Curriculum Corner, Light and Color, Light Waves and Matter
2. The Curriculum Corner, Light and Color, Polarization

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

1. The Calculator Pad, Light and Color, Problems #10 - #25

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

1. Light and Color: Cell Phone Radiation and Cancer

Standards:

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

Performance Expectation: High School Physical Science - Waves (HS-PS4-3)

Disciplinary Core Ideas: Physical Science - Waves

Wave Properties: HS-PS4.A.iii and **Electromagnetic Radiation: HS-PS4.B.i**

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