Wave Measurements

NASA SUMMER OF INNOVATION

UNIT
Physical Science -- Waves and Optics

GRADE LEVELS
4-6

CONNECTION TO CURRICULUM
Science and Mathematics

TEACHER PREPARATION TIME
1 hour

LESSON TIME NEEDED
3.5 hours *Complexity: Moderate*

DESCRIPTION
This lesson integrates a series of activities to introduce the measurement of waves. Activities guide the students to explore the relationship between frequency and wavelength and apply it to explain the Doppler effect.

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OBJECTIVES
Students will:

- Explore the relationship between frequency and wavelength.
- Demonstrate the Doppler effect using sound and extend the concept to light.
- Use the frequency-wavelength relationship and Doppler effect to explain NASA's research in astronomy.

NATIONAL STANDARDS

National Science Education Standards
Science as Inquiry
• Skills necessary to become independent inquirers about the natural world.
Physical Science
• Light, Heat, Electricity and Magnetism.
History and Nature of Science
• Science as a human endeavor.

Common Core State Standards for Mathematics
Number and Operations
• Understand the place value system.
• Generalize place value understanding for multidigit whole numbers.
Measurement and Data
• Convert like measurement units within given measurement system.
• Represent and interpret data.

MANAGEMENT
The activities in this lesson should be done with cooperative groups of three to four students. The Doppler effect demonstrator may be purchased or created following the procedures in Red Shift, Blue Shift prior to use with the students. The rounds with slits for the simple spectroscope also should be prepared by the teacher in advance of the lesson. The majority of the teacher preparation time will be in creating the Doppler effect demonstrator.

CONTENT RESEARCH

The inverse relationship between frequency and wavelength is fundamental to understanding wave phenomena and modern astronomy. The relationship explains the Doppler effect that is used by astronomers at NASA to determine the relative motion and rotation of celestial objects.

Key Terms:

- **Doppler Effect --** the observed shift in frequency of a wave due to relative motion between source and detector.
- **Wavelength --** the measured distance between identical points on successive waves.
- **Frequency --** the number of waves per unit time passing a given point.

LESSON ACTIVITIES

The listed sequence leads students from the basic relationship between wavelength and frequency to its application in explaining the Doppler effect.

Wavelength and Energy
Students will be introduced to the relationship between frequency, energy and wavelength using a rope, tape measure and stopwatch.
www.nasa.gov/pdf/319904main_The_Electromagnetic_Spectrum.pdf

What's the Frequency, Roy G. Biv?
Students create a physical model comparing the wavelengths and frequencies of red, green and violet light on adding machine tape.
http://imagine.gsfc.nasa.gov/docs/teachers/lessons/roygbiv/roygbiv.html

Introduction to the Electromagnetic Spectrum
This five-minute video helps reinforce the relationships found by the student teams with animations and physical data.
http://missionscience.nasa.gov/ems/emsVideo_01intro.html

Simple Spectroscope
Students build a simple spectroscope using a toilet paper tube and diffraction grating, then use the scope to observe the spectra of different light sources and draw their observations on a provided worksheet.
www.nasa.gov/pdf/319904main_The_Electromagnetic_Spectrum.pdf

MATERIALS

- *20 ft rope*
- *tape measure*
- *stopwatch*
- *adding machine tape*
- *set of red, green and violet pencils*
- *meter stick or ruler*
- *manila folder or cardstock*
- *4 books*
- *1 pair scissors*
- *diffraction grating*
- *paper tube (toilet paper roll)*
- *poster board 5 x 10 cm*
- *masking tape*
- *2 razor blades*
- *Spectrum tubes (if possible)*
- *Doppler effect demonstrator*

OR

- *plastic whiffle ball*
- *micro switch*
- *buzzer*
- *battery*
- *cord (3 m)*

Red Shift, Blue Shift
In this culminating activity, students get a chance to apply their understanding of the relationship between wavelength and frequency to explain the Doppler effect, first in sound and then in electromagnetic waves.
www.nasa.gov/pdf/319904main_The_Electromagnetic_Spectrum.pdf

ADDITIONAL RESOURCES

This applet shows the Doppler effect in a simple manipulative.
http://www.grc.nasa.gov/WWW/K-12/airplane/sndwave.html

DISCUSSION QUESTIONS

Each NASA activity includes discussion questions in the provided Student Data components.
Additional Questions:

- What does the shifting of a star's light towards the blue part of the spectrum tell us? *The star is approaching us.*

- If all observed galaxies are red-shifted, what does that tell us about the universe? *The universe is expanding.*
- Why does NASA need to be aware of the full electromagnetic spectrum? *If we study only visible light, we exclude approximately 90 percent of the information available.*

ASSESSMENT ACTIVITIES

Each activity includes a "Student Data Sheet."

- The sheet for the activity What Is the Frequency, Roy G. Biv? is a good pre-test of student understanding.
- Use the student sheet from Red Shift, Blue Shift as a final assessment.

ENRICHMENT

Each activity includes extensions to allow students to continue their learning experiences.

- Have students investigate other uses of the electromagnetic spectrum such as communications, heating and energy transfer.
- Have students investigate applications of the Doppler effect beyond determining the motion of stars, including: traffic speed radar, weather forecasting or military applications.