Light and the Electromagnetic Spectrum

Strand Transverse Waves

Topic Investigating light

Primary SOL PS.9 The student will investigate and understand the characteristics of transverse waves. Key concepts include
- a) wavelength, frequency, speed, amplitude, crest, and trough;
- d) the electromagnetic spectrum.

Related SOL PS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- e) numbers are expressed in scientific notation where appropriate;
- f) independent and dependent variables, constants, controls, and repeated trials are identified;
- g) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted;
- j) valid conclusions are made after analyzing data;
- k) research methods are used to investigate practical problems and questions;
- l) experimental results are presented in appropriate written form;
- n) current applications of physical science concepts are used.

PS.9 The student will investigate and understand the characteristics of transverse waves. Key concepts include
- b) the wave behavior of light;
- c) images formed by lenses and mirrors;
- e) technological applications of light.

Background Information

Transverse waves transfer energy in a direction perpendicular to the direction of disturbance in the medium. A vibrating rope is an example of a transverse wave. Although all points on the rope itself will only move up and down, wave pulses move perpendicularly along the length of the rope. Electromagnetic waves, such as light, are examples of transverse waves.

Transverse waves can be characterized by their properties, including their wavelength, frequency, speed, amplitude, crest, and trough. The *wave speed* is the speed with which a pulse moves along the rope. Wave speed (m/s) is the product of wavelength (m) and frequency (s). A *wavelength* is the distance from one peak, or *crest*, to the next. This is the same as the distance from one dip, or *trough*, to the next. The color of light is determined by its wavelength. *Frequency* of waves refers to how many peaks pass a point in a given time, usually one second. The amount of energy a wave carries is measured by its *amplitude.* The amplitude is equal to the height of the crest of the wave above the rest position. The brightness of a light will depend on its amplitude.

The *electromagnetic spectrum* is the range of possible frequencies of electromagnetic radiation. The wavelengths in the electromagnetic spectrum vary in size from very long radio waves the size

of buildings, to very short gamma-rays smaller than the size of the nucleus of an atom. Visible light is also represented within the electromagnetic spectrum, and each of the colors we see corresponds to a different wavelength of light.

Concave and *convex* lenses and mirrors are used to bend light rays and, thereby, change the focal point. These curved mirrors and lenses will enlarge or reduce the size of the image. Telescopes, eyeglasses, many rear-view mirrors on vehicles, and our own eyes are examples of concave and convex lenses and mirrors.

Materials

- Three small mirrors, a convex lens, and a concave lens for each group
- Target for each group
- Light source, such as a very strong flashlight, filmstrip projector, or a laser pen (if available)
- Long spring
- Masking tape
- Timer

Vocabulary

amplitude, concave, convex, crest, electromagnetic spectrum, frequency, lens, mirror, reflection, refraction, trough, wavelength, wave speed

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

In this activity, students will investigate the properties of light, lenses, and mirrors by using the materials provided and following the procedures below to set up a reflection/refraction relay.

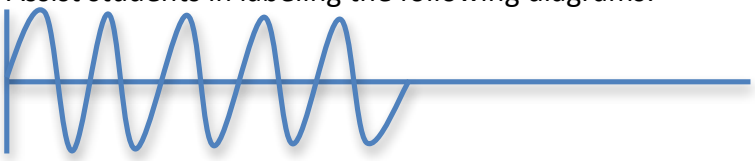
Reflection/Refraction Relay Design

1. Divide students into teams of four.
2. Have each team design a relay course that meets the following requirements. Students may *not* use their light source during the initial setup. The light beam must
   - begin travel from the starting point
   - reflect off of all three mirrors at some point
   - refract through the two lenses at some point
   - hit the target last.
3. Have each team do the following:
   - Shine the light from the starting point, and record the difficulties encountered.
   - Make and record modifications to the setup. Shine the light through again.
   - Repeat trials until the team is successful. Record all difficulties and modifications in the data table.
   - Draw a diagram of the final relay course. Make sure the path of light is indicated on the diagram.
   - Summarize the process of experimental design in a paragraph. Share the process with the class, emphasizing the role of the mirrors (e.g., angles of reflection of light) and the role of the lenses (e.g., concave spread or enlarged the beam, convex caused the beam to reduce or converge).

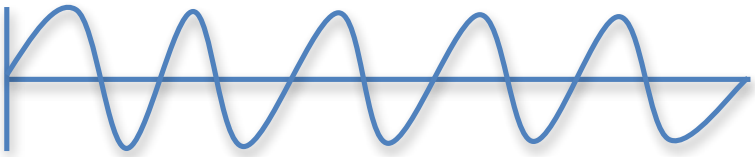
4. Have each team summarize the difficulties encountered and the modifications made for each trial. Also, have each team illustrate their successful relay course.

Transverse Wave, Part 1

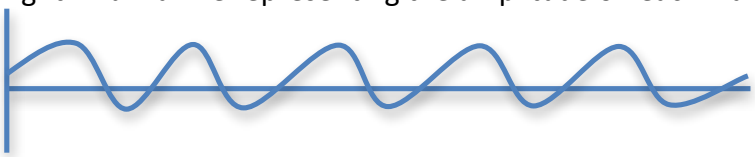
1. Place a long piece of masking tape on the floor to represent the "rest position" of a transverse wave. Place an "X" in the middle of the tape line to use as a reference point for determining frequency. Also mark 20 cm and 50 cm above and below the line. Select two students to hold a long spring along the tape line. Have one student keep his/her hand still while the other student moves his/her end side-to-side making the spring go above and below the "rest position." Ask students to create waves with the following characteristics:
   - Amplitude of 20 cm
   - Amplitude of 50 cm
   - Longest wavelength possible
   - Shortest wavelength possible
   - Highest frequency possible
   - Lowest frequency possible
2. Ask students to summarize the relationship among wavelength, frequency, and amplitude.
3. Assist students in labeling the following diagrams:

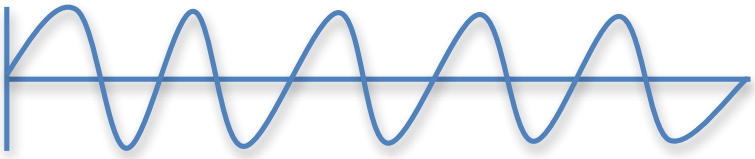


4. Label the crests and troughs on the following wave:



5. Amplitude is the distance between the rest position and the crest of a wave. The larger the amplitude, the brighter the light will appear. *Circle* the wave that will produce the brightest light. *Draw* a line representing the amplitude on each wave below.





6. Wavelength is the distance measured from one point on a wave to the same point on the next wave. For example, from crest to crest or from trough to trough. Label one wavelength on the wave below:

Transverse Wave, Part 2

1. Lead students through a discussion on the electromagnetic spectrum.
   - Begin with a drawing of the sun and the Earth, and lead students in a discussion of how energy gets from the sun to the Earth.
   - Draw waves showing how electromagnetic energy is transferred from the sun to the Earth. Ask students to identify the type of wave that was drawn (Answer: transverse). Tell students that energy from the sun is called radiation. Discuss other occurrences of radiation on the Earth.
   - Discuss with students that transverse waves that transfer radiation or energy are called electromagnetic waves. These waves are created by electrically charged particles that move.
   - Explain to students that there are different types of electromagnetic radiation existing in the universe. Show students a picture of the electromagnetic spectrum. Explain that electromagnetic radiation is classified according to wavelengths and frequencies.
   - Discuss the aspect of the spectrum humans can naturally see. Connect the behavior of the visible light in the prior activity to this section on the electromagnetic spectrum.
2. Divide students into seven groups. Assign each group a type of wave to research on the electromagnetic spectrum. The types of waves are radio, microwave, infrared, visible, ultraviolet, X-ray, and gamma ray.
3. Students should use various resources to complete their research (e.g., Internet, books, encyclopedias) and answer the Assessment questions listed below. Each group should design a short presentation on their section of the electromagnetic spectrum.
4. Have students research and present a wave and include the following:
   - Type of wave
   - Wavelength (expressed in scientific notation and standard form)
   - Frequency (expressed in scientific notation and standard form)
   - Approximate temperature (energy)
   - Three to five applications of the wave type
   - Three to five images, including one of the entire electromagnetic spectrum, illustrating the wave type

Assessment

- **Questions**
  - What is the relationship between wavelength and frequency?
  - Which wavelengths of electromagnetic radiation are most harmful to humans?
  - What determines the color of light, amplitude, or wavelength?

  - How is wavelength measured?
  - How is amplitude measured?
  - What is one application for each level of the electromagnetic spectrum?
- **Journal/Writing Prompts**
  - Draw the electromagnetic spectrum and describe which part(s) have the most energy and why.

Extensions and Connections (for all students)

- Have students research the difference between AM and FM radio waves. Report on why FM radio stations are more popular for music than AM stations. Ask them how XM radio stations are different from AM and FM stations.
- Have students keep a log of the electromagnetic waves students encounter through a week, keeping in mind only a small portion is visible!
- Have students be attentive of lenses and mirrors they see during a week. Record the type of lens or mirror, its use and its location. Compare logs at the end of the week to find patterns.
- Have students describe how eyeglasses and contacts help nearsightedness and farsightedness.
- Have students research how laser surgery can change the shape of eyes to improve vision.

Strategies for Differentiation

- Demonstrate an example of the Reflection/Refraction Relay Activity prior to allowing student groups to create their own.
- Use a digital camera to take a picture of each design; then allow students to identify difficulties encountered and modifications made on their photos.
- In Activity 2, Part 1, use specific questions to direct students through the summarization of relationships between wavelength, frequency, and amplitude.
- In Activity 2, Part 2, use the information collected on the various types of waves (step 3) to create information stations. Have students travel through the seven stations in order to collect the information about each type of wave on a foldable, labeling the foldable from left to right, with the longest wavelength on the left and the shortest on the right. Have them use an 11 x 7 piece of paper, folded long-ways in half, and cut into seven sections to create their foldable.