eLearning
P.O. Box 219 • Batavia, IL 60510
(800) 452-1261 • Fax (866) 452-1436
www.flinnsci.com • E-mail: flinn@flinnsci.com

FLINN SCIENTIFIC, INC
"Your Safer Source for Science Supplies"
Publication No. 91227

Wave Generator

Light, Energy, and Electron Structure

Introduction

How are wavelength and frequency related in a transverse wave? This demonstration allows your students to visualize the relationship between wavelength and frequency when the speed of light is constant, c = 20.

Concepts

- Transverse waves
- Wavelength
- Frequency
- Speed of light

Materials

Line Pattern Master
Wave Pattern Master
Marker, red, permanent or transparency
Overhead projector and screen
Scissors, 1 per student (optional)
Tape
Transparency sheets, 2

Safety Precautions

The materials in this demonstration are safe. Handle sharp cutting devices with care. Please follow normal laboratory safety guidelines.

Preparation

1. Obtain an overhead projector and place it 10 to 15 feet in front of a projection screen.
2. Make a transparency copy of the Line Pattern Master and the Wave Pattern Master (included).
3. Use a red-colored marker to completely color in the lone unshaded, outlined box on the Line Pattern Transparency.
4. As an option, the Line Pattern Master and Wave Pattern Master may be photocopied for each student ahead of time so that students may prepare their own line and wave patterns and follow along with the demonstration at their desks. This will help students to be involved as they see the inverse relationship between wavelength and frequency.

Procedure

1. Turn on the overhead projector and, if necessary, darken the room.
2. Place the Wave Pattern Transparency onto the overhead projector so that the projected wave images are horizontal. (Tape down if necessary.)
3. Place the Line Pattern Transparency over the Wave Pattern Transparency so that the projected image lines are vertical.
4. Adjust the focus of the overhead projector to produce a clear image of the white waves and the red mark in the wave patterns.
5. Start with the red line on the Line Pattern Transparency at one end of the Wave Pattern Transparency and then slowly slide the Line Pattern Transparency lengthwise across the Wave Pattern Transparency. The lines on the Line Pattern Transparency should be aligned perpendicular to the motion of the sheet.

6. Observe the motion of the black marks in the wave pattern images. Use the red mark in the wave patterns as a reference mark to represent the wave front of the three waves. How do the speeds of the wave fronts compare? Is the red mark traveling at the same lengthwise speed in each wave? Is the transverse motion of the red mark the same for each wave? If not, what is the relationship between the wavelength and the transverse motion of the red mark? [*Answer:* The red mark travels at the same speed for each wave, representing the constant speed of light. The transverse motion is much quicker for the smaller wavelength waveform, showing that the frequency is higher for the smaller wavelength waveform.]

Student Procedure (optional)

1. Fold the Wave Pattern sheet in half along the dashed line.
2. With the sheet folded, and the dotted lines of the wave patterns facing out, start at the creased end of the paper and cut out the wave patterns with scissors. *Note:* Do not cut all the way across the paper.
3. Once the patterns are cut out, unfold the sheet to display the full cutout wave pattern slits in the paper. If necessary, smooth out and flatten the sheet so that it will lay flat.
4. Use a red-colored marker to completely color in the lone unshaded, outlined box on the Line Pattern sheet.
5. Tape the Line Pattern sheet to a tabletop so that it is flat and the lines are aligned vertically on the page.
6. Place the cutout Wave Pattern sheet over the Line Pattern sheet so that the wave pattern slits run horizontally on the page. (The black marks and red mark from the Line Pattern sheet should be visible in the wave pattern slits.)
7. Slide the Wave Pattern sheet lengthwise (horizontally) over the Line Pattern sheet to observe the motion of the waves as represented by the "motion" of the black marks and the red mark.
8. Follow along with the class discussion.

Disposal

The materials may be saved for future demonstrations.

Tips

- These materials can be saved and reused indefinitely.
- The Wave Pattern cutouts can be laminated to protect them for future use.

Discussion

All electromagnetic radiation travels at the same constant speed through a vacuum. This constant speed is known as the *speed of light* and is designated with the symbol c, where $c = 2.998 \times 10^8$ m/s in a vacuum. Experiments have shown that electromagnetic radiation travels in a similar fashion to that of water waves in a ripple tank or pond—that is, electromagnetic radiation travels in the form of waves, more specifically transverse waves. A *transverse wave* is described as a wave in which the disturbance of the wave pattern travels at a right angle to the direction of motion of the wave. Conversely, for a *longitudinal wave* (also known as a compression wave), the wave pattern disturbance travels along the same direction as the direction of motion of the wave. Sound waves are examples of longitudinal waves. See Figure 1.

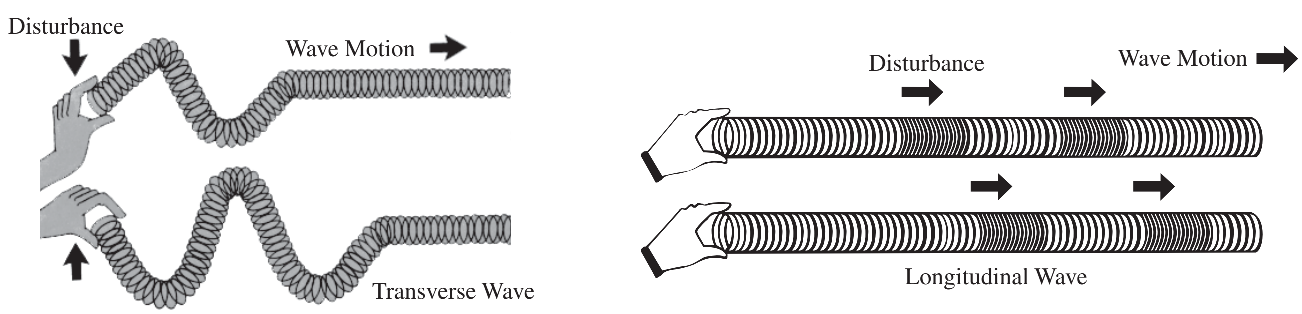


Figure 1.

Reminiscent of all waves, electromagnetic waves have a wavelength, frequency, speed, and an amplitude (see Figure 2). The relationship between the wavelength and the frequency of a wave is determined by the speed of the wave (the speed of light for electromagnetic waves) according to the equation below.

$$c = \lambda \upsilon$$

c = speed of light (speed of the wave)
λ = wavelength of the wave (Greek letter *lambda*)
υ = frequency of the wave (Greek letter *mu*)

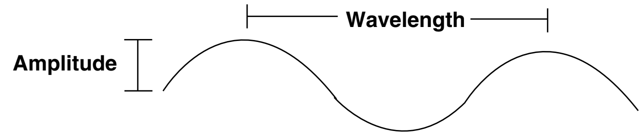


Figure 2.

It can be seen from the equation that as electromagnetic radiation wavelength decreases, the frequency must increase. This relationship between frequency and wavelength is called an *inverse* relationship.

This demonstration illustrates this inverse relationship between the frequency and the wavelength for waves that travel at the same speed. The three wave patterns provided (A, B, and C) have three different wavelengths, 1½″, 3″, and 4½″, respectively. The red mark in each wave image represents the wave front (the leading edge of the wave). As the line pattern is moved over the wave patterns, the red mark travels at the same lengthwise speed which shows that the three wave fronts are traveling at the same speed. By observing the red mark in each wave pattern, it can be seen that the red mark in the smaller wavelength waveform, A, “travels” up and down much more frequently than for the longer wavelength patterns (B and C). The *transverse* motion is quicker for the smaller wavelength wave—it has a higher frequency. More specifically, every time the red mark travels an entire wavelength in the longer wavelength waveform (C), the red mark travels up and down a total of three times in the smallest wavelength waveform (A). Waveform A’s wavelength is three times smaller than waveform C’s wavelength, and therefore the frequency of A must be three times faster than C, because the waves are traveling at the same speed.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, interactions of energy and matter

Reference

Bilash, B.; Gross, G.; Koob, J. K. *A Demo a Day: A Year of Chemical Demonstrations;* Flinn Scientific: Batavia, IL, 1995; pp 108.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Wave Generator* activity, presented by George Gross, is available in *Light, Energy, and Electron Structure,* part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

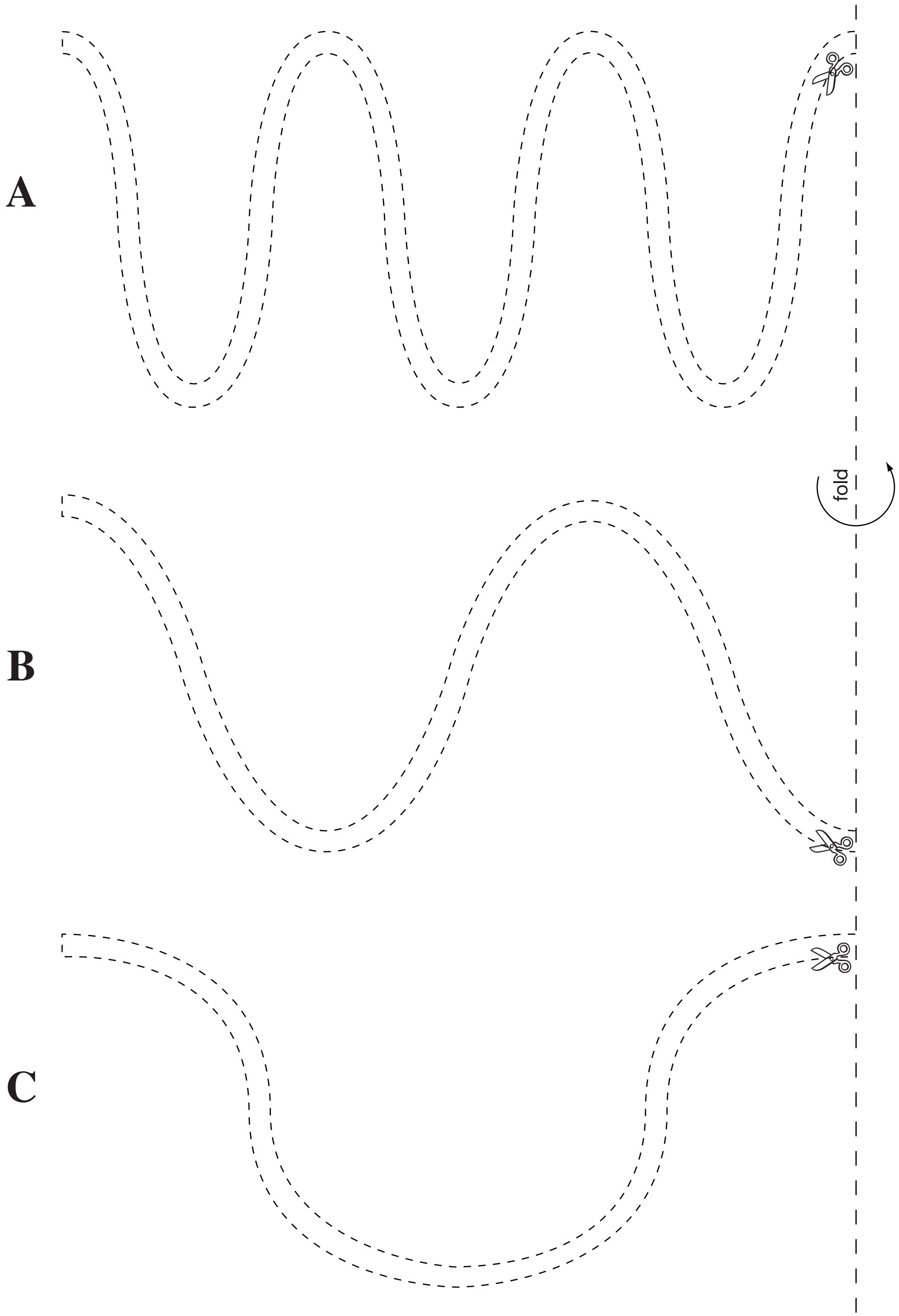
Materials for *Wave Generator* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Transverse Wave Demonstrator* available from Flinn Scientific.

Catalog No.	Description
AP6252	Transverse Wave Demonstrator

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Wave Pattern



Line Pattern