ACTIVITY: Wavelength and Energy

Description:

Shaking a rope permits students to feel the relationship between wavelength, frequency, and energy.

Objective:

To demonstrate the relationship between wave frequency and energy in the electromagnetic spectrum.

National Education Standards:

Mathematics
- Measurement
- Data analysis, statistics, & probability

Science
- Evidence, models, & explanation
- Change, constancy, & measurement
- Abilities necessary to do scientific inquiry
- Motions & forces
- Transfer of energy

Technology
- Understand relationships & connections among technologies & other fields

Materials:

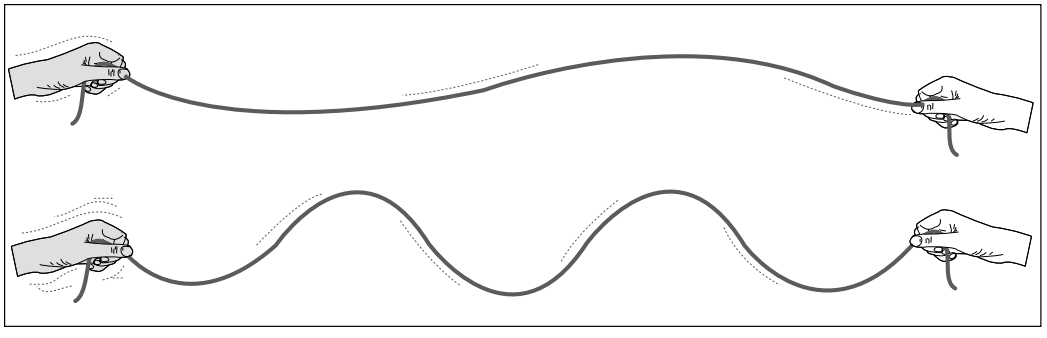
Rope – 50-ft. length of cotton clothesline
Tape measure
Stopwatch or clock with second hand

Procedure:

1. Select two students to hold the rope. Have each student stand in an aisle or in opposite corners of the classroom so that the rope is taut between them.
2. While one end of the rope is held still, have the other student shake the opposite end up and down at a moderate but steady rate.
3. Ask other students to observe the wave patterns created in the rope. Point out wave crests and troughs. Ask your students to measure the *wavelength* and *frequency* of waves reaching the other student. The wavelength is the distance from wave crest to wave crest (or wave trough to wave trough). The wavelength can be measured by having one student stand next to the rope where a wave crest is repeatedly formed and having a second student stand where the next crest is formed. Measure the distance between the students. Frequency is the number of waves reaching the far end of the rope each second. Frequency can be estimated by counting the number of times the student shakes the rope each second.
4. Tell the student shaking the rope to shake it faster. Again estimate the wavelength and frequency.
5. Tell the student shaking the rope to shake the rope as fast as he or she can. Again, estimate the wavelength and frequency.
6. Stop the demonstration and ask the student shaking the rope if it is easier to produce low frequency (long wavelength) or high frequency (short wavelength) waves.

Background:

This activity provides a graphic demonstration of the relationship between energy and wavelength. The student shaking the rope will find that creating many waves each second takes much more energy than producing only a few waves per second. High-frequency waves (short wavelength) represent more energy than low-frequency (long wavelength) waves. Astronomers find the relationship between wavelengths, frequency, and energy very useful. Radio waves



$$E = \frac{hc}{\lambda}$$

$$E = hf$$

Planck's Constant = 6.63×10^{-34} J·s

f is the frequency in hertz

λ is the wavelength in meters

from astronomical objects have very long wavelengths and low frequencies. The waves are generated by relatively quiet processes. Gamma rays, on the other end of the electromagnetic spectrum, have very short wavelengths and high frequencies and represent the most violent processes in space. The frequency of electromagnetic energy coming from an object tells astronomers much about how that object was created and what was happening at the time the energy was emitted into space.

Management and Tips:

The quality of the demonstrations can be greatly enhanced by using a wave demonstration spring. These springs are available from school science supply catalogs for a few dollars. The springs are long coils and when stretched and agitated, produce excellent waves. The increased mass of the spring over the cotton clothesline enhances the wave motions. If a strobe light is available, the appearance of the wave motions can be enhanced by playing the light on the moving rope or spring and adjusting the strobe frequency. A Slinky® can also be used to demonstrate wave motion but it will work best if the Slinky® is placed on a long table and the spring is shaken from side to side.

Permit other students to shake the rope so they can feel, as well as see, the relationship between frequency, wavelength, and energy.

Assessment:

Make sure students understand the relationship between frequency and wavelength and the amount of energy required to produce the waves. Collect and compare the student sheets.

Extensions:

- Invite a hospital medical imaging specialist to talk to the class about the use of high-frequency electromagnetic waves in medical diagnosis.
- Make an overhead projector transparency of the spectrum chart on page 00. Ask the students to relate energy to the electromagnetic wavelengths depicted.