LAB 16. WAVES

Questions

- What types of behavior do waves exhibit?
- How can we define the velocity of a wave?
- How are the wavelength, period, and speed of a wave related?

Background

Consider what happens when you toss a pebble into a quiet pond. The pebble disturbs the surface of the water, creating ripples. Suppose a leaf is floating on the water's surface some distance away from the spot where you threw in the pebble. After the stone is tossed into the pond, the leaf bobs up and down as the ripples pass the leaf's position. Why would the leaf move up and down? How is this example different from the case of a leaf that is carried down a river by flowing water?

A wave is a propagation of energy. Electromagnetic waves (light, radio, etc.) can propagate through vacuum; other types of waves need a medium to pass through. The wave is a disturbance in that medium. The ripples on the pond are an example of water waves.

A wave shape that repeats itself is *periodic*. The distance between successive crests, successive troughs, or any other pair of identical points on the wave is called the *wavelength*, λ. The maximum displacement of any point from the equilibrium position is called the *amplitude*, A.

The number of complete waves that pass a single position in a unit of time, such as a second, is the wave frequency, f. The time between waves passing that position is the wave period, T. The period is related to the frequency by $T = 1/f$.

Waves may be either transverse, longitudinal, or a combination. In a transverse wave, the motion of individual points in the medium is perpendicular to the direction of propagation of the wave (i.e., up-down or left-right as the wave moves forward). In a longitudinal wave, the individual points move parallel to the direction of propagation (i.e., forward-backward as the wave moves forward). Instead of having crests and troughs, longitudinal waves have regions of compression and rarefaction. Many waves in nature, such as ocean waves, are a combination of these two limiting types.

Equipment

long coil spring, mounting hardware, stopwatch, meter stick, tape measure, loose coil spring (Slinky), stopwatch; rectangular tub of water, water wave source, blocks, large funnel

Activities

You may do the activities in any order.

1. Longitudinal waves in a slinky

1. Lay the Slinky on the floor or table and hold one end securely. Move the free end of the spring to try to create a pulse that compresses the spring. How do you accomplish this? Is the coil compressed along its entire length at any instant?

2. Estimate the speed of a pulse. Do this by making rough measurements of the time the pulse takes to travel a known distance. Show your measurements, calculation, and estimate. Also determine if it is possible to change the wave speed, and describe what factors you must change to accomplish this.

3. Set up a standing wave pattern in the Slinky. This takes some work, because the pulse encounters a lot of friction. Do a victory dance. Call over the instructor to show the pattern.

2. Transverse waves in a coil spring

1. Clamp both ends of the spring. Practice making single wave pulses that travel from one end of the spring to the other (and back). I find that the simplest way to do this is to sharply tap the spring near one end.
2. Estimate the speed of a single wave pulse by measuring how long it takes to travel a known distance. Show your measurements and calculations below.

3. Identify the factors you must control to do change the speed (not frequency: propagation speed!) of the wave.

4. Generate another wave pulse on the spring. Observe the reflection of this pulse at the end of the spring. The wave that arrives at the end is called the **incident** wave. What is the displacement of the coils as the incident wave passes? Is it positive (up) or negative (down)?

5. What is the direction of the displacement of the coils as the **reflected** wave passes? A sketch may help you explain.

3. Wavelength and frequency of a standing wave

Now you will study standing waves in the same coil spring. You will need to create and maintain at least three different wave patterns. The wavelength of the standing waves can be measured by using a ruler, measuring tape, or meter stick.

1. Practice creating and maintaining standing wave patterns with several different numbers of nodes.
2. Find the period of one pattern by timing a large number (say, 25) of cycles. Enter the timing data into the Table 1 and calculate the period.
3. Measure the wavelength of the standing wave. Note that the distance between adjacent nodes (stationary positions) equals *half* a wavelength.
4. Without changing the tension or length of the spring, create a standing wave pattern with a different number of nodes. Repeat parts 2 and 3 for the new standing wave.
5. Repeat parts 2 and 3 again with one more frequency, for a total of three sets of data. Try to sample a range of frequencies and wavelengths!

Table 1. Standing Waves in a coil spring

Oscillations	Total Time (s)	Period (s)	Wavelength (m)	Speed (m/s)

Data Workup

1. Calculate the speed (speed = distance/time = wavelength/period) of the wave for each set of measurements. Record the values in Table 1.

2. Using a spreadsheet or your own graph paper, make a graph of the wavelength (vertical axis) vs. period (horizontal axis) from your data in Table 1. Scale your graph to use at least half of each axis. Enter the units in the axis labels. Title your graph.

3. Fit the graph with a straight line. What is the slope of the line?

4. What is the physical meaning of the slope of the line?

5. If you change the period of a wave in the string, does the speed of the wave increase, decrease, or stay the same? Do your data and your graph support your answer?

4. Water waves

What are waves like in two dimensions? Here you will observe waves on the surface of water. You will also observe how these waves move near obstacles and barriers.

Water surface waves are complicated! The crashing surf at the beach is obviously different from a simple sine wave. Nevertheless, they do illustrate some features common to all types of waves. We use water surface waves in this activity to look more closely at the reflection of waves from barriers.

Procedure

Put some water in the tub. Allow enough for the entire bottom to be covered to at least 5 cm depth.

1. Generate circular wave pulses by dipping your finger in the water at different positions. Make wave trains by rhythmically moving your finger up and down. What happens to the waves when they reach the side of the tub?

2. Tap a side of the tub. Describe the waves that are produced.

3. Hold the wave source vertically in the tub, so that the tray is parallel to the short edge of the tub. Generate a straight wave pulse by moving the source toward and away from the edge of the tub. How does the pulse travel across the surface of the water?

4. Make standing waves by rhythmically moving the source back and forth. Can you make standing waves with different wavelengths? Sketch the pattern of nodes in the standing waves you produce.

5. Does the location of the source in the tub affect the standing waves that you can produce?

6. Can you make standing waves if you hold the source at an angle to the side of the tub? If you can, sketch the pattern of nodes in the standing waves you produce.

7. Place an inverted funnel in the tub. Generate a single straight wave pulse and observe how it behaves when it reaches the funnel. Describe what happens.

8. Tilt the tub so that it has a shallow end and a deep end. Create a wave pulse in the deep end and observe it as it travels to the shallow end. Describe what happens.

9. With the tub still tilted, create a straight wave pulse that travels diagonally in the tub. Observe how it behaves as it moves from the deep end to the shallow end. Describe what happens.

Lab Grade

Present this sheet with all questions answered and your graph from Activity 3.