Experiment 10

WAVES   (Fall 2023 version 2)

EQUIPMENT

2 long springs (slinky and coiled spring)
Meter stick

WAVE program
Stopwatch

INTRODUCTION

The purpose of this experiment is to investigate the properties of two types of waves, the superposition of waves, and the principle of standing waves.

Longitudinal and Transverse Waves

These are two general types of waves *transverse* and *longitudinal*. Waves on a string are an example of transverse waves. Light and radio waves are also examples of transverse waves. Sound waves, on the other hand, are an example of longitudinal waves. Consider sound waves traveling through the air. The sound waves consist of areas of compression, where the air density is greater, and rarefaction, where the air density is reduced. It is not the air itself but rather a pulse of energy moving through the air that produces sound waves. Of course, sound waves can be heard and felt, but not seen.

Wave Superposition

When two or more waves meet, they add together to produce a different waveform. Complex waves, those that are not of a pure tone or single frequency, are made from the *superposition*, or addition, of several other waves. Your voice, waves on a string, and some electrical waves are examples of complex waves. You will use a computer program to observe how complex waves are produced. The WAVE program allows you to choose the characteristics of two waves which are to be superimposed. The computer then shows the two original waveforms and the result of their addition.

Standing Waves

Standing waves are a special example of wave interference. If two sets of waves having equal amplitude and wavelength pass through one another in opposite directions, the waves produce areas of constructive and destructive interference that can be observed as positions of maximum and minimum vibration. These positions are referred to as antinodes and nodes respectively.

By vibrating a length of string that is fixed at one end, a train of transverse waves will be sent down the string and then reflected back. If the tension in the string is adjusted, standing waves can be set up in the string. The number of standing waves produced is determined not only by the tension in the string but also the mass per unit length of the string and the vibrating frequency. This demonstration will use a driver to produce an incident wave train along a string fixed at one end. Tension in the fixed end is produced by suspended masses. By varying the tension, different numbers of standing waves can be produced.

The laboratory instructor will demonstrate this type of standing waves using the driven string system at the front of the lab.

As noted above, standing waves are characterized by *nodes* and *antinodes*. In the case of the vibrating string, nodes are points on the string where no vibration is apparent. At these points there is no displacement of the string. Antinodes are points of maximum vibration and displacement of the string.

PROCEDURE

A. Longitudinal and Transverse Waves

1. Attach a piece of tape to a single coil of a spring, about one or two feet from the end, and stretch the spring along a smooth floor with you at one end and your partner at the other.

2. While your partner holds one end still, reach a short distance down the spring's length and gather the coils toward you. Quickly release the gathered coils. Repeat this several times and then let your partner try it. Notice the direction in which the pulse travels and the direction in which the coils of the spring move. Pay special attention to how the piece of tape behaves as the longitudinal pulse goes through the spring.

3. Continue producing longitudinal pulses and observe the speed of the pulse as it travels down the length of the spring. Vary the speed of the pulse by changing the tension in the spring.

4. While your partner holds one end of the spring still, "pluck" the spring sideways. Do this until you are able to send a pulse shaped like a hump down the length of the spring. Observe the motion of the coils and the piece of tape as the pulse travel through the spring. Observe the speed of the transverse pulse. Vary the speed of the pulse by changing the tension in the spring.

5. Pluck the spring as in Step 4, but pay special attention to how the pulse behaves when it reaches the end of the spring held stationary by your partner. (Notice whether the pulse inverts or remains the same).

Q1: See data sheet to answer question 1 now.

6. Pluck your end of the spring at the same time as your partner. Try plucking from the same side and from opposite sides. Observe what happens when the pulses meet along the spring.

Q2. See data sheet to answer question 2 now.

7. Using the tightly coiled spring, stand three or four meters apart and hold the spring so it doesn't sag much. While one partner uses the stopwatch to time, strike the spring with a ruler and watch the pulse reflect back and forth. Measure the time for the pulse to make 3 round trips. (Six trips down the spring.) Measure the distance between you and your partner with the meter stick. Double this and record your round trip distance. Divide your calculated round trip distance by 3 to determine the time for one round trip. Determine the speed of the wave on the spring by dividing your round trip distance by this time.

Q3. See data sheet to answer question 3 now.

You have observed that the speed of a wave depends on the medium (the spring with different tension is another medium).

B. Wave Computer Simulation

The application **"the Physics Classroom"** allows you to simulate and view the motion of single waves and then to add two or three waves together and view the result of wave addition or superposition.

This program is bookmarked on the browser in the lab. It is easy to use and reasonably self explanatory.

You will use this program on part B starting on page 63 of procedure below.

Experiment 10
DATA SHEET

Name: _____

Section: _____

QUESTIONS:

PART A

1:
a) Describe the motion of the tape as longitudinal pulses traveled through the spring. Compare its motion to that of the direction of the pulse along the spring. What happened to the pulse when it reached the stationary end of the spring?

b) Describe the motion of the tape as transverse pulses traveled through the spring. Compare its motion to that of the direction of the pulse along the spring. What happened to the pulse when it reached the stationary end of the spring?

2: How did the two pulses produced at opposite ends behave when they met along the spring? Elaborate on the fact that there are two possible conditions. Illustrate this with a diagram for each.

3: How did you vary the speed of the pulses in the spring? _____
_____

Table for Part A. # 7

Distance measured between partners	Round Trip Distance	Time for 3 round trips	Time for 1 round trip (previous time/3)	Velocity of Wave (m/s)

PART B

4:
  Which two characteristics affect the frequency? For each, answer if it is directly or inversely proportional to frequency. **Use** $v = \lambda f$ **and solve for** $f \, (\text{frequency})$ **to answer below. Show this below.**

_____ directly proportional   or   inversely proportional
_____ directly proportional   or   inversely proportional

  What affect does changing each of these have on the graph? **USE SLIDERS ON PROGRAM TO CHANGE PROPERTIES.** Explain below.

  Amplitude:_____
  Wavelength:_____
  frequency:_____   _____

5: When the velocity is negative, which direction does the wave travel? _____
When the velocity is positive, which direction does the wave travel?_____

6: If the wavelength of a wave is 80 m and it is moving at 320 m/s, what is its frequency? _____.

Use $v = \lambda f$ to answer this question. Show work.

7: a. **Set all the controls the same except for amplitude.** Draw a graph of the 2 waves and their resultant wave when the peaks of the 2 waves coincide. Explain what you drew (i.e., comment on how peaks and valleys add or subtract).

   b. Next draw a graph of the 2 waves and their resultant wave when the 2 waves pass peak to valley. Use "destruct" button to change position of the wave(s). **See figure below.** Explain what you drew.

| ? | T+L | STANDING L | STANDING T | DESTRUCT | CONSTRUCT | BEAT 2 | BEAT 1 |

8: What happens when two waves differing only in wavelength are superposed? Illustrate this with a diagram.

9: What are the conditions that determine a standing wave. Click on "STANDING T" to observe and describe what wave properties of the two wave that interfere you observe.

10: Explain how you might change the pitch of a string on a guitar. What property of the string do you vary? Does this change the wavelength of the wave on the string? This should have been demonstrated using the string wave generator in If so, how? (larger or smaller?)