Name Period Date

70 Catch a Wave

Purpose

To observe important wave properties

Required Equipment/Supplies

Slinky™ spring toy, long form
portable stereo with two detachable speakers
Doppler ball (piezoelectric speaker with 9-volt battery mounted inside 4"-diameter foam ball)

Discussion

When two waves overlap, the composite wave is the sum of the two waves at each instant of time and at each point in space. The two waves are still there and are separate and independent, not affecting each other in any way. If the waves overlap only for some duration and in some region, they continue on their way afterward exactly as they were, each one uninfluenced by the other. This property is characteristic of waves and is not observable for particles the size of billiard balls. Obviously, you've never seen a cue ball collide with another billiard ball and reappear on the other side! However, sound and water waves, if they are weak enough, behave this way. That is, two sound waves can overlap so that *no* sound results! Impressive!

Procedure

Part A: Longitudinal vs. Transverse Waves

Light is a *transverse* wave, meaning that the wave vibrates back and forth perpendicular to the line of propagation. Sound is a *longitudinal* wave, meaning that the wave vibrates along the line of propagation.

Observe transverse waves.

Step 1: Have your partner hold one end of a long Slinky and carefully—so as not to get it tangled or kinked—stretch it out on a smooth (non-carpeted) floor or a long counter top. Give the Slinky a rapid jerk by shaking it to one side then back so that you create a wave pulse that travels to your partner. Be sure your partner holds the other end fixed. Repeat several times, observing what happens to the wave pulse as it travels to your partner and back.

1. How does the Slinky move with respect to the wave pulse?

2. Is the pulse transverse or longitudinal?

3. Why does the amplitude of the pulse decrease as it travels from its source?

4. How does the reflected pulse differ from the original pulse?

5. What happens to the wavelength of the pulse as it travels to and from your partner?

Observe reflection of waves.

Step 2: Attach a piece of string about a meter long to one end of the Slinky. Have your partner hold the free end of the string. Send a pulse along the Slinky.

6. How does the reflected pulse differ from the original pulse?

Observe change in wave speed.

Step 3: Increase the tension in the Slinky by stretching it. Send a pulse along the Slinky. How does the tension affect the speed of the pulse? Does the tension in the Slinky affect other wave properties as well?

Observe longitudinal waves.

Step 4: Repeat steps 1 through 3 but this time jerk the Slinky back and forth along the direction of the outstretched Slinky. What kind of wave is produced? Record your observations.

Observe the sum of two waves.

Step 5: Now for some real fun! This time you and your partner will create equal-sized pulses at the same time from opposite ends of the Slinky. It may require some practice to get your timing synchronized. Try it both ways—that is, with the pulses on the same side and then with the pulses on opposite sides of the line of propagation. Pay special attention to what happens as the pulses overlap. Record your observations.

Observe interference of sound waves.

Step 6: Detach two speakers from a portable stereo with both speakers in phase (that is, with the plus and minus connections to each speaker the same). Play in a mono mode so the signals of each speaker are identical. Note the fullness of the sound. Now reverse the polarity of one of the speakers by interchanging the plus and minus wires. Note that the sound is different—it lacks fullness. Some of the waves from one speaker are arriving at your ear out of phase with waves from the other speaker.

Now place the pair of speakers facing each other at arm's length apart. The long waves interfere destructively, detracting from the fullness of sound. Gradually bring the speakers closer to each other. What happens to the volume and fullness of the sound? Bring them face to face against each other. What happens to the volume now?

Part B: Standing Waves—Resonance

Have your partner hold one end of the Slinky. Shake the Slinky slowly back and forth until you get a wave that is the combination of a transmitted wave and its reflection—a standing wave—like the *fundamental* (or the first harmonic) shown in Figure A.

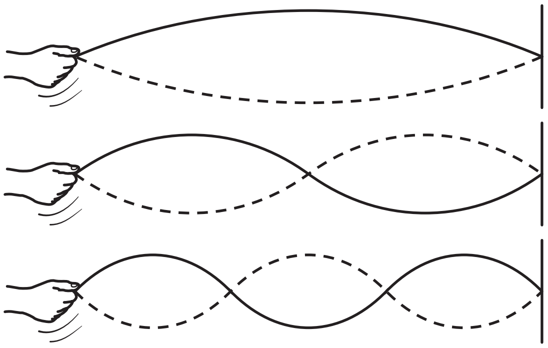

Fig. A

7. How long is the wave compared to the length of the Slinky?

Observe standing waves.

Step 7: Now shake the Slinky at a higher frequency so that a second-harmonic standing wave is created.

8. How long is the wave compared to the length of the Slinky?

Observe harmonics.

Step 8: See how many other harmonics you can create. Record your observations.

Part C: The Doppler Effect

You are now going to investigate what happens when either the source or the receiver of waves is moving. For example, when a car whizzes by on the road, the pitch of its engine is higher when approaching and lower when receding. This change of frequency due to motion is called the Doppler effect.

Similarly, the whine of an airplane engine changes its pitch as it passes overhead. If the plane moves faster than the speed of sound, the Doppler shift is replaced by a shock wave, which produces a "sonic boom." It is interesting to note that any object traveling at supersonic speed creates its own shock wave—whether or not it is a sound emitter.

The Doppler effect occurs with *any* wave phenomenon (including light and other electromagnetic radiation) whenever there is relative motion between the source and receiver. For example, the decrease of frequency for the light of a receding star gives it a *red shift*. An approaching star is seen to be *blue shifted*. The Doppler effect is far reaching.

Observe Doppler effect.

Step 9: Play catch with your partner using a Doppler ball. How does the movement of the ball affect the pitch of the sound?