28 Computer Activity: Wave Properties
Catch a Wave

Purpose

To simulate superposition and other important properties of waves using a computer.

Required Equipment and Supplies

Apple II Series computer
Good Stuff software
2 tuning fork resonators

Discussion

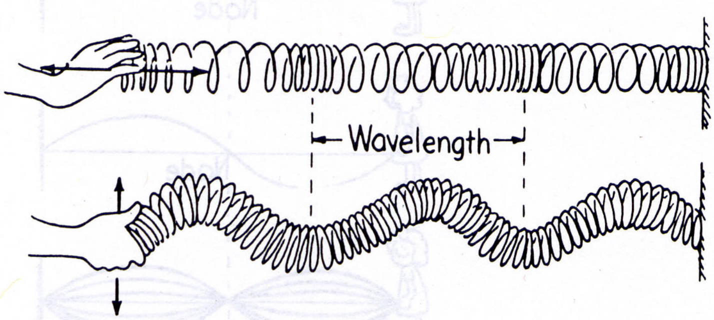
When two waves combine, the composite wave is the sum of the two waves at each instant at each point in space. The two waves are still there and are separate and independent, not affecting each other in any way. Each wave can be extracted from the sum by subtracting the other wave from the resultant wave. After the duration in which the two waves combine, they continue on their way, each exactly as it was before. The resultant wave exists no longer. In this activity, you will study this and other fascinating properties of waves on a computer.

Part A: Longitudinal Waves Contrasted with Transverse Waves

Procedure

Step 1. Boot the *Good Stuff* disk and select the program "Longitudinal Waves." Even though sound is a longitudinal wave, it is often represented in illustrations as sinusoidal waves *transverse* to the direction of propagation—like waves in a rope shaken up and down. For sound, the medium is air, but in this simulation the medium is represented as vertical lines on the computer screen. Sound is represented as the waves moving horizontally through the lines. Observe the motion of the medium (lines).

1. How do the waves move with respect to the medium?



2. Does the medium *propagate* from one side of the screen to the other? Are the molecules of air that carry sound across a room the same molecules that strike your ear?

Part B: Waves on a String

Procedure

Step 2. Return to the main menu of *Good Stuff* and select the "Waves on a String" program. This program shows how two wave pulses—one square and the other triangular—combine. Press [Return] to view the interaction of the square and the triangular pulses. Observe how the pulses pass through each other in "slow motion" by pressing the [S] key. This enables you to single-step their motion a "frame" at a time.

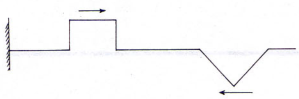


Figure 28.1

1. What is the result of the two waves approaching each other as shown in Figure 28.1, when overlapped? How about Figure 28.2?

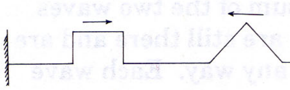
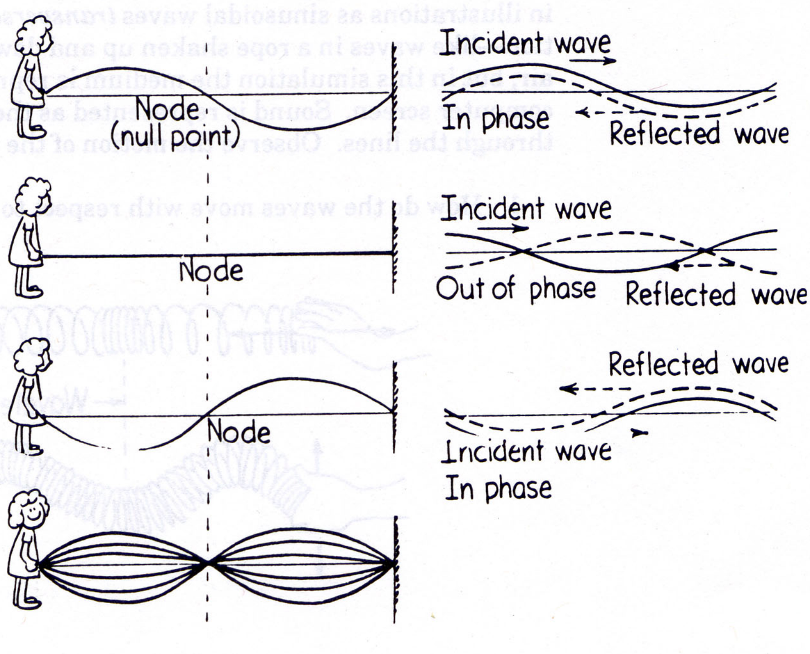


Figure 28.2

Step 3. Return to the main menu of *Good Stuff* and select the "Sum of Two Waves" program. Select the option "Traveling Waves" and continue. This program adds the two sine waves at the top of the screen and displays the resultant waveform on the bottom. Observe how the waves move across the screen. Observe how the waves add in "slow motion" by pressing the [S]



key. For example, if the two waves were on the same string at the same time, what you would actually see is shown by "Sum." Press the arrow keys to change the two waves to be added. The "n" refers to the "wave number," the *reciprocal* of the wavelength, or number of waves per unit length. In this case, n is the number of waves that fit across one computer screen.

Change the value of n_1 so that it equals n_2. What is the sum of two waves of equal wavelength (i.e., that have the same wave number)? Is the wavelength of the resultant the same or different from the constituent waves?

Change the value of n_1 to 4, 5, 7, or 8. Describe the sum of two waves of unequal wavelength. Listen to your teacher demonstrate beats by using two tuning forks of slightly different frequencies. How does what you hear compare with what you see?

Change the value of n_1 to 3. Why is the sum of the two waves "frozen?"

Go back to the menu and select the "Standing Waves" option and press return. Observe the sum of the two waves—neat! How is this sum different from the others you have observed?

Carefully observe the motion and character of the constituent waves. What are the directions of the constituent waves relative to each other? How do their wavelengths and speeds compare?

Part C: The Doppler Effect

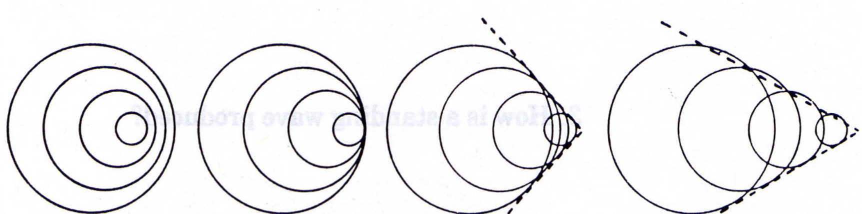
Discussion

You are now going to investigate what happens when either the source or receiver of waves is moving. For example, when a car whizzes by on the road, the pitch of its engine is higher when it approaches and lower when it recedes than the pitch you would hear if you were in the car.

Similarly, the pitch of an airplane changes as it passes overhead. If the plane moves *faster* than the speed of sound, a shock wave or "sonic boom" may result. It is interesting to note that any object traveling at supersonic speed creates its own shock waves—whether or not it is a sound emitter. The Doppler effect occurs with *any* type of wave—including light—whenever there is relative motion between the source and receiver. For example, when a star recedes, its "pitch" drops—like the pitch of a receding fire engine's siren. This lowering of frequency for light is called a *red shift*. For an approaching star, the increase in light frequency is called a *blue shift*. The Doppler shift is qualitatively the same for light as it is for sound, although the actual equations are different (due to the lack of a medium for electromagnetic waves).

Let the speed of the source or the receiver be v and the speed of the sound waves c. The speed of the source or the receiver compared to the speed of the waves, is v/c, commonly called the *Mach Number*.

Let's investigate and see.



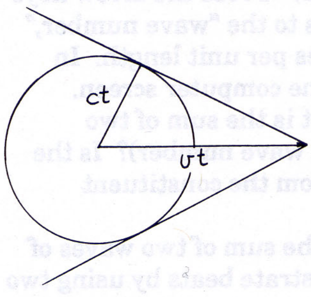


Figure 28.3

Step 4. Return to the main menu and select the "Doppler Effect" program. Use the default settings (Mach Number (v/c) = 0.5) and observe the Doppler effect for a moving source. Notice how the clicks gradually become less frequent as the source passes the receiver. Repeat for a moving receiver. How does the Doppler shift compare?

Step 5. Now, select "Moving Source" and increase the Mach Number to 0.8, 1, 1.4, 2, 3.5, etc. Observe the formation of the bow wave (shock wave) when the Mach Number is *greater* than 1. What happens to the angle of the cone as the Mach Number increases? Repeat for "Moving Receiver."

Step 6. Using a protractor and a ruler, measure the half-angle of the cone created by the shock wave as shown in Figure 28.3. What is the angle for Mach Number equal to 1.4? A Mach Number equal to 2?

Step 7. Study Figure 28.3. Draw a circle within and tangent to the triangle (cone) of the shock wave. Draw the radius from the source (the center of the circle) so that it is perpendicular to the shock wave. Label the distance, ct, that the *wave* traveled in time, t, to reach the shock wave. Now label the distance, vt, that the *source* traveled in the same time, t, to reach the vertex of the shock wave. Make a right triangle from the center of the circle to the shock wave along the radius to the vertex back to the center of the circle. How is the sine of the half-angle, θ, related to the Mach Number?

Step 8. Any kind of wave can be used to illustrate the Doppler effect. The Doppler effect in light is used by astronomers to find out whether a star is approaching or receding from the earth. If it's approaching, it's blue shifted; if it's receding, it's red shifted. Select option 3, "Light." The Doppler effect of light waves is similar to that for sound waves. One difference is that nothing can go faster than light in a vacuum. Another is that at high speeds the source frequency slows down; moving clocks run more slowly because of relativistic time dilation. Compare the Doppler effect for light to that for sound with $v/c = 0.90$. How do they compare?

Analysis

1. Compare and contrast the propagation of longitudinal and transverse waves.

2. Contrast the reflection of the pulses when the end is free and when the end is fixed.

3. How is a standing wave produced?

4. Suppose a plane were approaching you at Mach 0.5 with a siren blaring at 1000 Hz. What frequency would you hear as the siren approached? After it passed you by?

5. Suggest a way in which two speakers both playing a tone of 128 Hz in phase can be arranged so that there is one point between the two speakers where no sound is heard. Write a mathematical expression for the separation distance, $d = a + b$, in terms of wavelength, λ. In this case, a is the distance from one speaker to the point where no sound is heard and b is the distance from that point to the other speaker.

6. Two tones have frequencies of 256 Hz and 260 Hz. What is the beat frequency?

7. When a trumpet and a violin both play the same musical note they sound very different. Speculate as to why notes sound different even though the pitch is the same.