What Do You Think?

After a cost of millions of dollars, the Philharmonic Hall in New York City had to be rebuilt because the sound in the hall was not of high enough quality. Now named Avery Fisher Hall, it has excellent acoustics.

• What does it mean to have “dead space” in a concert hall?
• What is the secret to good acoustics?

Record your ideas about these questions in your Active Physics log. Be prepared to discuss your responses with your small group and the class.

For You To Do

1. Work with two partners. Two of you will operate the Slinky and one will record the observations. Switch roles from time to time. Stretch the Slinky to about 10 m.

While one end of the Slinky is held in a fixed position, send a pulse down the Slinky by quickly shaking one end.
a) What happens to the pulse when it reaches the far end of the Slinky?

2. Send a series of pulses down the Slinky by continuously moving one of its ends back and forth. Do not stop. Experiment with different frequencies until parts of the Slinky do not move at all. A wave whose parts appear to stand still is called a standing wave.

3. Set up the following standing waves:
   - a wave with one stationary point in the middle
   - a wave with two stationary points
   - a wave with three stationary points
   - a wave with as many stationary points as you can set up

4. You can simulate wave motion using a graphing calculator. Follow the directions for your graphing calculator to define a graph and set up the window. Use the following for the Y-VARS, and select FUNCTION. Use the Y= button to enter these values:
   \[ Y_1 = 4 \sin x \]
   \[ Y_2 = 4 \sin x \]
   \[ Y_3 = Y_1 + Y_2 \]

   Press GRAPH to view the waves.

   a) Describe the two waves you see on the screen.
   b) Can you see that \( Y_3 \) is equal to \( Y_1 + Y_2 \)?
   c) Use the vertical axis on the screen to find the amplitude of the crest of each wave. How do they compare?

   You can edit the \( Y_1 \) and \( Y_2 \) functions to show waves \( Y_1 \) and \( Y_2 \) moving from the left to the right, as follows:
   \[ Y_1 = 4 \sin (x - \pi/4) \]
   \[ Y_2 = 4 \sin (x + \pi/4) \]
   \[ Y_3 = Y_1 + Y_2 \]

   d) How many waves do you see on the screen? Compare the amplitude of the third wave to those of the first two waves.

   Edit again.
Patterns and Predictions

\[ Y_1 = 4 \sin (x - \pi/2) \]
\[ Y_2 = 4 \sin (x + \pi/2) \]
\[ Y_3 = Y_1 + Y_2 \]

\( e \) Describe the waves you see on the screen. Look for locations on the waves that always remain zero. These locations are called nodes.

\( f \) Draw the waves you see on the screen on graph paper. Label the nodes.

Edit again.

\[ Y_1 = 4 \sin (x - 3\pi/4) \]
\[ Y_2 = 4 \sin (x + 3\pi/4) \]
\[ Y_3 = Y_1 + Y_2 \]

\( g \) Describe the waves you see on the screen.

\( h \) Draw the waves you see on the screen on graph paper. Label the nodes.

\( i \) Compare the amplitude of each wave. How does the amplitude of the third wave compare to that of the first and the second wave?

Edit again.

\[ Y_1 = 4 \sin (x - \pi) \]
\[ Y_2 = 4 \sin (x + \pi) \]
\[ Y_3 = Y_1 + Y_2 \]

\( j \) Describe the waves you see on the screen.

\( k \) Draw the waves you see on the screen on graph paper. Locate the positions of the nodes.

\( l \) Measure the amplitude of the first wave. What is the amplitude of the second wave? How do they compare?

5. Use a ripple tank to explore what happens when two sources of circular water waves “add together” in the tank.

6. As directed by your teacher, set up two speakers to explore what happens when two identical single tone sounds are broadcast.

7. As directed by your teacher, use a double slit to explore what happens when two beams of laser light are “added.”
FOR YOU TO READ

Wave Interference

The wave that you sent down the Slinky was reflected and traveled back along the Slinky. The original wave and the reflected wave crossed one another. In the previous activity, you saw that waves can “add” when they pass one another. When waves “add,” their amplitudes at any given point also “add.” If two crests meet, both amplitudes are positive and the amplitude of the new wave is greater than that of the component waves. If a crest and trough meet, one amplitude is positive and one is negative. The amplitude of the resulting wave will be less than that of the larger component wave. If a wave meets its mirror image, both waves will be canceled out.

In this activity, you created a pattern called a standing wave. Two identical waves moving in opposite directions interfere. The two waves are constantly adding to make the standing wave. Some points of the wave pattern show lots of movement. Other points of the wave do not move at all. The points of the wave that do not move are called the nodes. The points of the wave that undergo large movements are called the antinodes.

The phenomena that you have observed in this activity is called wave interference. As waves move past one another, they add in such a way that the sum of the two waves may be zero at certain points. At other points, the sum of the waves produces a smaller amplitude than that of either wave. This is called destructive interference. The sum of the waves can also produce a larger amplitude. This is called constructive interference. The formation of nodes and antinodes is a characteristic of the behavior of all kinds of waves.
Reflecting on the Activity and the Challenge

Imagine you were told that adding one sound to another sound in a space could cause silence. Would you believe that light plus light can create interference fringes, where dark lines are places where no light travels? You might have thought such strange effects are magic. In a Slinky, a wave traveling in one direction and a wave traveling in the opposite direction create points on the Slinky that do not move at all. That is experimental evidence for the interference of waves. Now you know that dead spaces and dark lines can be explained by good science. You can approve funding to study phenomena that appear strange as long as some measurements on which all observers can agree are used in supporting the claims.

Physics To Go

1. What is a standing wave?

2. Describe in your own words how waves can “add.”

3. What properties must two pulses have if they are to cancel each other out when they meet on a Slinky?

4. Make a standing wave using a Slinky or a graphing calculator. Draw the wave. Label its nodes and antinodes.

5. What is the distance, in wavelengths, between adjacent nodes in a standing wave pattern? Explain your thinking.

6. In photography, light can scatter off the camera lens. A thin coating is often placed on the lens so that light reflecting off the front of the thin layer and light reflecting off the lens will interfere with each other. How is this interaction helpful to the photographer?

7. Two sounds from two speakers can produce very little sound at certain locations. If you were standing at that location and one of the speakers was turned off, what would happen? How would you explain this to a friend?
8. Makers of noise reduction devices say the devices, worn as headsets, “cancel” steady noises such as the roar of airplane engines, yet still allow the wearer to hear normal sounds such as voices. How would such devices work? What principles of waves must be involved?

**Stretching Exercises**

An optical hologram is a three-dimensional image stored on a flat piece of film or glass. You have probably seen holograms on credit cards, in advertising displays, and in museums or art galleries. Optical holograms work because of the interference of light. Constructive interference creates bright areas, and destructive interference, dark areas. Your eyes see the flat image from slightly different angles, and your brain combines them into a 3-D image.

Find out how holograms are made. Describe the laboratory setup for making a simple hologram. If your teacher or you have the equipment, make one!