Waves and Sound

In these activities you will explore properties of waves on a string and sound waves in air columns. Each group will have a *Sound and Wave Discovery Pack* that contains the following:

Super Slinky
Sound Pipes (2)
Singing Rods (2)
Space Phone
Boomwhackers (8)
Snaky Helical Spring
Doppler Ball
Standing Wave kit

Below are some suggested activities using some of the items in the kit. There is also an activity on sound level using an iPad app. You won't have time to do them all in detail.

Wave speed on a snaky helical spring

Method 1

Let two people hold ends of the long coiled spring stretched to moderate tension. One person generates a pulse on the string by quickly moving his end once up and down. Measure the time for the pulse to travel down the spring and back one or more times. Determine the speed by v = distance/time.

Predict how you think the speed will change if you increase the tension?

Now increase the tension, measure the speed, and check your prediction.

Method 2

Now with the tension (and length, L) the same as in one of the above measurements, establish a standing wave pattern by having one person move his end repeatedly up and down while the other person holds his end fixed. Adjust the frequency of the up and down motion to obtain standing waves consisting of one loop ($\lambda = L/2$), two loops ($\lambda = L$), three loops ($\lambda = 3L/2$), etc. (A loop is the distance from node to node, where a node is where the spring is barely moving.) In each case, measure the frequency, f (oscillating/sec), and wavelength, λ (m), and determine the speed (m/s) using $v = f\lambda$.

Questions:
Are the standing wave frequencies multiples of the fundamental (lowest) frequency?

Are the speeds determined from different standing wave patterns the same?

Are these speeds similar to the speed obtained using method 1?

Transverse and Longitudinal Waves

Lay the super slinky on the floor and stretch it between two people. (The floor should be smooth.) Show how you can generate a transverse wave, as in the above activity using the 'snaky spring'.

Now show how you can generate longitudinal waves – either a single pulse or a periodic wave. How would you use longitudinal waves in the slinky to describe the propagation of sound waves?

Standing Wave Generator

The standing wave generator consists of a string connected to a battery powered motor which acts as a vibration source. The string is hung vertically with the motor at the lower end. The tension in the string is determined by the weight of the motor. Note how standing waves consisting of one, two, or (possibly) three loops can be obtained by adjusting the length of the string.

Measure the frequency of the vibrations using a stroboscope. Measure the wavelength by using the fact that each loop is one-half of a wavelength. Determine the speed of the wave for the different standing wave patterns using $v = f\lambda$.

The speed can also be calculated using the relationship $v = \sqrt{F/\mu}$, where $F = mg$ is the weight of the motor (in newtons) and $\mu = m_s/L$ is the mass per unit length (kg/m) of the string. How does this calculated speed compare with the measured speeds?

Speed of Sound

The speed of sound can be determined by finding resonances (standing waves) in an air column, similar to the way you can found the speed of waves on a string. In this case we use a hollow tube which is closed at one end and open at the other. The sound source, placed near one end of the tube, will be a sinusoidal tone at frequency f generated by the iPad e-scope app (or a tuning fork).

Method 1

The closed end will be a node (least air vibration) and the open end will be an anti-node (maximum vibration). The length of the closed-open tube can be adjusted by pushing a ping-pong ball up and down the tube using a meter stick. With the sound source near the open end, you can position the ping-pong ball so that you can hear resonances. The length change from one resonance to another is $\Delta L = \lambda/2$, which can be determined by noting how far you move the meter stick from one resonance to another. Thus, you can measure λ and determine the speed from $v = f\lambda$.

How does this measured speed compare with the accepted speed of sound?

Method 2

An alternative way to adjust the length of the closed-open tube is to lower one end of the tube in a container of water. This gives very sharp resonances. You simply measure the length of the tube above water at the resonances and use $\Delta L = \lambda/2$ to find λ.

The speed of sound in a gas depends on the molecular weight of the gas. (How? Does it increase or decrease if you increase the molecular weight?) Try this: Put an Alka-Seltzer in the water to generate CO_2. Measure the speed of sound. Is it different from the speed of sound in air?

Method 3

An additional way of determining the speed of sound is to use the 'sound pipes'. These are corrugated plastic pipes open at each end. You can hold one end and whirl it around and produce various resonances. At slow speed you hear the first harmonic (fundamental) f_1 and at higher speeds you hear the higher harmonics ($f_n = nf_1$, $n = 1, 2, 3, \ldots$). The frequencies can be measured using the e-scope iPad app. The wavelengths can be measured using $\lambda_n = 2L/n$.

Boomwhackers

The 'boomwhackers' consist of eight hollow plastic tubes of different lengths. They are labeled according to their musical note, which depends on the tube length. If you whack the tubes on something (someone's head, your knee, ...), you can note the dependence of frequency on length. A group of students could use the whackers to play a tune. (Sheet music is provided.)

The whackers also come with end caps. For the open-open tube, the fundamental wavelength is $2L$. For the open-closed tube, the fundamental wavelength is $4L$. By capping one end, you can observe that the frequency decreases by one octave (a factor of two).

Doppler Effect

The Doppler effect refers to the change in measured frequency of a source depending on the speed of the source and/or the observer. For example, when a source approaches or moves away from the observer, the observed frequency increases or decreases by an amount that depends on the speed of the source. The Doppler effect is obvious when whirling the sound pipes. You will hear a modulation of the frequency as the open end moves toward and away from you as it is whirled. The faster the pipes are whirled, the greater is the frequency modulation.

The Doppler effect can also be demonstrated by placing a buzzer in a Nerf ball. As it is thrown back and forth, its observed frequency increases and decreases.

Sound Level (decibels)

The iPads have a sound level app called Decibel 10^{th}. Use this to measure the sound level in various environments. What is the lowest sound level you can measure? What is a typical sound level in a classroom? What sound levels would be considered quite high?

The decibel scale is a log scale. Each change in 10 dB corresponds to a change of a factor of 10 in the sound intensity in watts/m^2. A change in 20 dB would correspond to a change of a factor of $10^2 = 100$. A change in 30 dB would be a factor of $10^3 = 1000$, etc. It can be shown that if you double the distance from a point source of sound, then the sound level decreases by 6 dB. This is hard to accurately observe due to background noise. Try it.

Further Study

Go through the Sound and Waves Discovery Pack and explore how you can use some of the additional items in a classroom. Each kit includes a packet of instructions for using most of the items in the kit. Items not covered in this workshop include the 'singing rods' and the 'space phone'. Also, you can use the 'sound pipes' to demonstrate the Bernoulli effect.

The Sound and Waves Discovery Pack was purchased from Arbor Scientific (http://www.arborsci.com). Their website is a good source of information (written and videos) on how to effectively use their products in the classroom.