GUIDE: Present the Audio Filter outreach exercise using the following steps.

I.   Convey the information in the Overview page of the exercise. In brief, you will explain that this lab is about using electronic circuits called "filters" to alter the frequency content of sounds, as an mp3 player's equalizer does. The students will design and build these filters and listen to the effect they have on the music coming out of their mp3 player.

Show the picture of the final filter circuit shown on the Outreach webpage Outreach:Audio Filter:Breadboard:stage 4. Hold up one the audio kits in a bag to show them the parts they will be using to build the circuit.

Explain that when we talk about the frequency content of sound, we mean that sounds are actually sinusoids (notes) added together to create a sound waveform. The filter circuit will selectively alter signals with certain frequencies to make them less loud. This will affect the quality of the sound, making it seem to have more treble or more bass.

Explain that it is therefore important to understand sinusoids and how they behave in electronic circuits. It will turn out that complex numbers are a convenient way of representing sinusoids. So some time will be spent understanding both sinusoids and how they may be represented by complex numbers.

Having mastered representation of sinusoids by phasors, a filter circuit will be analyzed. The analysis will provide a means of designing a filter that allows certain frequencies to pass through. The students will build the filter and listen to its effect on sounds, but first there is math to be learned.

II.   Tell the students that the first step on the journey to building a filter is to understand that all waveforms may be thought of as summations of sinusoids. Use the Outreach webpage Outreach:Audio Filter:Fourier Theory:Examples that has formulas for creating a square wave and a triangle wave from a summation of sinusoids. Write the formulas on the board, and have the students use their graphing calculators to show that the first three terms of these formulas give reasonable approximations to a square wave and to a triangle wave. Ask the students what the fourth and fifth and nth terms of the formulas would be.

III.   Refer to the Outreach:Audio Filter:Sinusoids:Magnitude Frequency & Phase webpage for your presentation of how to measure the magnitude (i.e., amplitude), frequency, and phase shift of a sinusoid. Talk about how these quantities may be extracted from a plot of the sinusoid. Walk through the example on the webpage.

To add interest to the process, you may use an iPhone oscilloscope app, (such as Faber Acoustical SignalScope), that allows you to plot the waveform of sound from the microphone. Sing or whistle a note, or use a tuning fork or musical instrument to create a note, and capture a portion of the waveform. Have a student help you draw a careful picture of the waveform on the board. Then have the students help you extract the magnitude, frequency, and phase shift of the waveform. Note that the waveform is not precisely sinusoidal, but you can still make out a magnitude, frequency, and phase shift.

Now have the students complete Outreach:Audio Filter:Worksheet I.

III.   Point out that working with sinusoids normally means having to use many trigonometric formulas for sums of angles and that this is tedious. Then let the students in on a secret: complex numbers may be used to represent sinusoids and perform calculations with them without having to use trigonometric identities. Present the information about transforming sinusoids to phasors on the webpage Outreach:Audio Filter:Sinusoids:Phasors.   Emphasize the connection between complex numbers and 2-dimensional vectors, and the connection between the rectangular and polar forms of complex numbers via the trigonometry of right triangles.

Have the students complete Outreach:Audio Filter:Worksheet II.