# Waves and Sounds

Introduction

For this activity, we will explore the key components of waves and sound using the iPad custom applications, *Waves & Sound* and *SoundSynth*. You will be able to see and hear how changing these parameters alters the audio and the waveform.

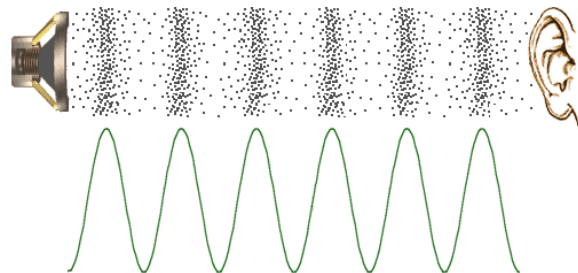*Where do we observe waves in the real world?*

What is sound?

So...if a tree falls in the forest, and no one is around to hear it...does it still make a sound?
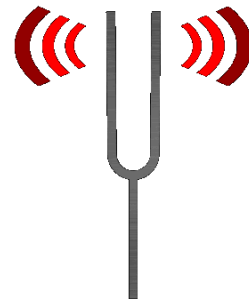
Materials

You will be given the following materials for this activity:

• iPad
• Headphones (or you can use your own)
• Pen / Pencil

Sine Waves

Sine waves are the building blocks of sound. In fact, **ALL** signals can be created by combining sine waves.

Sine Wave = Frequency

Cycle = One repetition of a wave's pattern
Frequency = The number of cycles per second (measured in Hz)
Period = Time duration of one cycle (the inverse of frequency, $P = 1/f$)
Wavelength = The length of one period of a wave
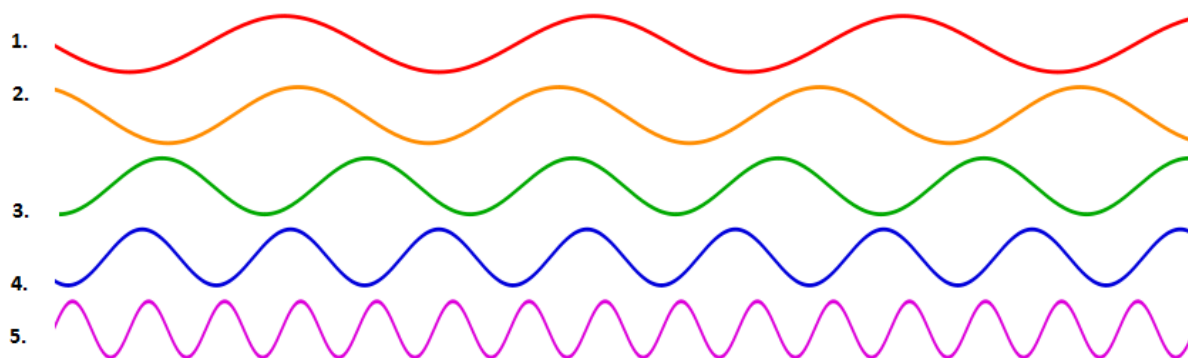**Amplitude** = A measure of it's change over a single period

Figure 1: Five sine waves (X-axis = time, Y-axis = amplitude)

1. *Draw lines on each of the sine waves, splitting them into single cycles.*

2. *The sine wave with the highest frequency is _____, and the sine wave with the lowest frequency is _____.*

3. *The sine wave with the shortest period is _____, and the sine wave with the longest period is _____. (*remember Period = the inverse of frequency)*

4. *The sine wave with the shortest wavelength is _____, and the sine wave with the longest wavelength is _____.*

5. *What relationships exist between frequency, period, and wavelength?*

Using an iPad to Generate Waveforms

We used to need a ton of bulky hardware to create these signals (oscilloscope, function generator, cables, and a speaker). Now, we can do all of this using software.

1. Open the *Waves & Sound* app on the iPad. This app allows you to choose a waveform and change the *amplitude* and *fundamental frequency* parameters.
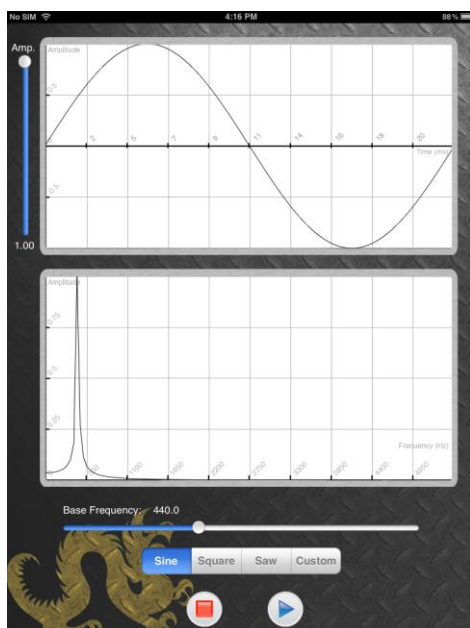

Figure 2: Waves & Sound App

2. Using your headphones, take a couple of minutes to explore the different waveforms (sine, square, saw). Also, you can tweak the amplitude and fundamental frequency. To hear your waveform, press the play button.

*** Adjust the volume on the iPad to avoid uncomfortably loud tones before hitting play.**

3. What changes to the sound occur when you*:*
Change waveforms? Raise/lower the amplitude? Alter the fundamental frequency?

4. Can you create a sine wave with a frequency of 500 Hz and an amplitude of 0.5? A square wave with a frequency of 800 Hz and an amplitude of 0.7.? A saw wave with a frequency of 300 Hz and an amplitude of 0.4?

Signal Analysis on iPad

Sine waves are the building blocks of sound. In this activity, we will take a closer look at sine waves and their properties. While exploring the *Waves and Sound* app, you heard and saw different types of waveforms. Something you may not have been able to guess from seeing and hearing these different signals is that they can all be created by combining simple single frequency sin waves. Remember **ALL** signals can be created by combining sine waves.

Signal Analysis

1. We will be using the *Waves & Sound* app again. The top window displays the *waveform* and displays time in milliseconds*.* The bottom window shows the *frequency spectrum (Hz).*

2. Make sure you select "Sine". On the *waveform* plot, you should see one period of a sine wave.

3. Move the frequency slider under the *frequency spectrum* until the frequency value is set as close to 500 Hz as possible.

4. *Where do you see the peak in the frequency spectrum?* _____

5*. How many frequencies occur in a sine wave?* _____

Square and Sawtooth Waves
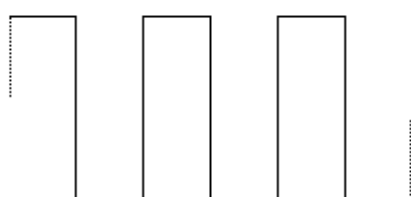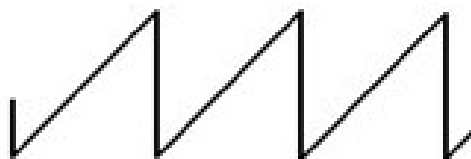
(a) Square Wave   (b) Sawtooth Wave

Figure 3: Example Waveforms

The spectrum shows us the frequencies and amplitudes (height of the peak) of the sine wave needed to create the waveform. Let's explore some of those complex waveforms you saw earlier.

1. Select square wave. Set the frequency to 500 Hz (or as close as you can get). Raise the amplitude to 1.00 to see higher peaks in the *frequency spectrum.*

2. You should notice that for the *square wave* there are peaks for more than one frequency in the *spectrum.* How many sine waves does it take to make this wave? _____ How does this sound different from a sine wave?

3. *Estimate the values in Hz for the 4 peaks beyond the* **fundamental frequency.** *(Hint: they should be multiples of the fundamental frequency)*

4. Peak 1 = _____ Peak 2 = _____ Peak 3 = _____ Peak 4 = _____

5. Is there a pattern or relationship you notice in the frequencies (Hz) of a square wave? What happens to the amplitudes of the peaks as the frequencies increase?

6. See if you can draw your own square wave by using your finger in the *waveform* plot. Do you see the same patterns? (See Fig 3.)

Fundamental Frequency = the lowest frequency of a sound, and usually the most dominant frequency.

7. Now, select saw wave. Keep the frequency at 500 Hz and leave the amplitude at 1.00.

8. How many sine waves make up the sawtooth wave? _____ How did the sound change?

9. *Estimate the values of the peaks beyond the* **fundamental frequency.**

10. Peak 1 = _____ Peak 2 = _____ Peak 3 = _____ Peak 4 = _____ Peak 5 = ____

     Peak 6 = _____ Peak 7 = _____ Peak 8 = _____ Peak 9 = _____

11. What is the pattern you notice for the frequencies (Hz) of a sawtooth wave?

12. See if you can draw your own sawtooth wave in the *waveform* plot. (See Fig 3.)

Draw your own Waveform

The next activity will demonstrate how **ANY** waveform can be reduced to individual sine waves. Each group will be drawing their own waveform, taking note of how the wave looks and sounds. Then, using the *SoundSynth* application, students will attempt to recreate their waveform by carefully using the information in the *frequency spectrum* and mapping the frequencies and amplitudes onto the *SoundSynth* frequency spectrum.

1. For this activity, everyone needs a partner. One partner needs to open *Waves & Sound*, and the other partner should open *SoundSynth.*

2. As you have seen, the *Waves and Sound* app gives you the option of creating your own waveform, by using your finger to draw in the waveform window.

3. One team member will draw a wave and choose a fundamental frequency in the *Waves & Sound* app.

4. Next, on the other iPad, teams will work together to recreate the frequency spectrum in the *SoundSynth* app, using the information from the frequency spectrum in the *Waves & Sound* application (where you drew your wave).

5. *Do the two waveforms that you have created sound the same?*

   Do the two waveforms look the same?

Harmonics

The peaks beyond the *fundamental frequency* in the last activity area called *harmonics.* While a sine wave is a pure tone, made of only one frequency, other waves (square, sawtooth, etc.) are made up of a sin wave and its *harmonics.* The harmonics of a frequency are just integer multiples of the fundamental frequency. As you saw in the last activity, if our fundamental frequency is 100 Hz, then our 2nd harmonic is the fundamental frequency multiplied by 2 (100 Hz x 2 = 200 Hz). We are going to explore harmonics using the *SoundSynth* iPad application.

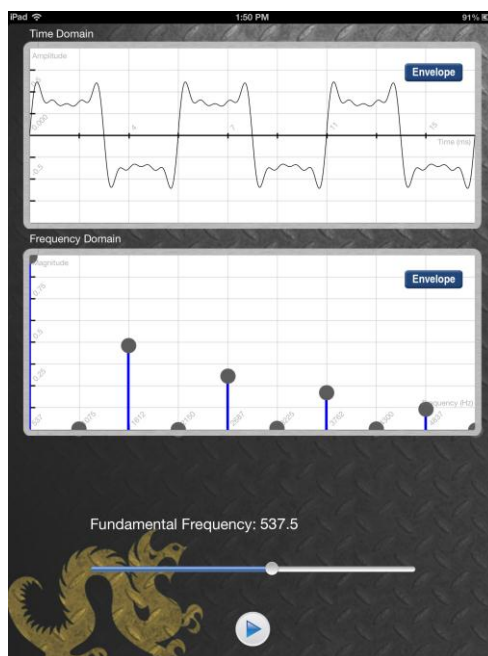1. Open the *SoundSynth* application on the iPad

Figure 4: SoundSynth iPad app

2. You should see the *waveform* and *frequency spectrum* again. On the bottom of the screen, you will see a slider which controls the fundamental frequency. Set this to 220 Hz.

3. Raise the amplitude of the left most dot on the frequency spectrum (this controls the amplitude of the fundamental frequency). This is an example of a pure tone or _____ wave, which we discussed earlier.

4. To create a mixed tone, we need to add another sine wave. Find the dot which is directly to the right of the fundamental. Raising and lowering this dot controls the amplitude of our 2nd harmonic. Look at the frequency label under the dot on the frequency spectrum.

   What is the relationship between this value and our fundamental frequency?

5. Raise this slider to the top, giving us the maximum amplitude.

   What does this new tones sound like? Do you hear two distinct tones or one blended tone?

6. Move the amplitude and fundamental frequency sliders around and see what types of tones you can create.

Find the Harmonics Game

1. For this game we will use the *Waves & Sound* iPad app.

2. We will not be using headphones for this activity.

3. Select sine wave.

4. The instructors will ask a student to generate a specific fundamental frequency.

5. The first goal is to have everyone, using their ears, to match the frequency.

6. Once the group has found the *fundamental frequency*, it should be easy to generate the *harmonics.* Each person will be assigned a different *harmonic.* Once everyone is at their correct frequency, we should hear a the combinations of frequencies as a blended single tone.

Some "Cool" Applications of Sound

1. The average range of human hearing is from 20 Hz to 20,000 Hz (20 kHz). As we get older or damage our hearing (lots of loud music, etc.), that range decreases. You
can test your own hearing at www.onlinetonegenerator.com

   My hearing range is from: _____ Hz to _____ Hz

   There is a ringtone called the "Mosquito Ringtone" that older people can't hear because it rings at very high frequencies.
http://www.noiseaddicts.com/2011/06/mosquito-ringtones/

2. We can generate a frequency spectrum from whole songs, not just individual waveforms. Let's look at a spectrum analyzer visualization for some real music in iTunes. This visualization shows the left/right frequencies and amplitude of the music as it is playing.