Lecture 29 - Sound

For a great page on music acoustics which I will be using a lot in this lecture: http://www.phys.unsw.edu.au/music/

A very cool, open source, sound editor: http://audacity.sourceforge.net/

Properties of Sound

Sound is generated by an oscillation and propagated as a longitudinal wave or pressure wave.

We can hear sounds between ~20Hz and ~20kHz. Probably you can hear higher frequency sounds than me. (It seems I can only hear to about 17kHz. In ten years time you may also only hear to this frequency.)

Pressure waves

Sound can be represented as a longitudinal wave

\[ D = A \sin(kx - \omega t) \]

The change in pressure from the background pressure \( P_0 \) in response to a volume change is related to the bulk modulus \( B \)

\[ \Delta P = -B \frac{\Delta V}{V} = -B \frac{A(D_2 - D_1)}{A(x_2 - x_1)} \]

which in the limit of \( \Delta x \to 0 \) is

\[ \Delta P = -BAk \cos(kx - \omega t) \]

Displacement and pressure

\[ D = A \sin(kx - \omega t) \]

\[ \Delta P = -BAk \cos(kx - \omega t) \]
\( \Delta P \) is the sound pressure level, the deviation from the background pressure.

**Loudness and decibels**

Our sensitivity to the loudness of sound is logarithmic, a sound that is ten times as intense sounds only twice as loud to us. The sound level \( \beta \) is thus measured on a logarithmic scale in **decibels** is

\[
\beta = 10 \log_{10} \frac{I}{I_0}
\]

\( I_0 \) is the weakest sound intensity we can hear \( I_0 = 1.0 \times 10^{-12} \text{W/m}^2 \)

Some examples of different sounds loudness in decibels can be found [here](#).

Our hearing is not equally sensitive to all frequencies, you can test your hearing [here](#).

**Standing Waves on a string with both ends fixed**

\[
k = \frac{2\pi l}{\lambda} = \pi, 2\pi, 3\pi, 4\pi, \ldots \text{ etc.}
\]

or \( \lambda = 2l, l, 2/3l, l/2, \ldots \text{ etc.} \)

\[
f = \frac{v}{\lambda} = \frac{v}{2l}, \frac{v}{l}, \frac{3v}{2l}, 2vl, \ldots \text{ etc.}
\]

If we number the modes \( n = 1, 2, 3, 4, \ldots \) (Where \( n = 1 \) is the fundamental mode).

\[
\lambda = \frac{2l}{n} \text{ and } f = v \frac{n}{2l}
\]

When we refer to a harmonic, we are describing the frequency as a multiple of the fundamental frequency.

**Making Sound - String Instruments**

The note in **string instruments** is generated by exciting a vibration and promoting a particular vibration in the string.
String instruments also use the body of the instrument to amplify the sound. We can see the standing wave patterns of objects with Chladni Patterns. Some examples on a violin and a guitar. And now with lasers.

Open and closed pipes

\[ l = \frac{\lambda}{2}, \lambda = 2l, f = \frac{v}{2l} \]

Fundamental, First Harmonic

\[ l = \frac{3}{2} \lambda, \lambda = \frac{2l}{3}, f = \frac{3v}{2l} \]

First Overtone, Second Harmonic

\[ l = \frac{5}{4} \lambda, \lambda = \frac{4}{5} l, f = \frac{5v}{4l} \]

Second Overtone, Fifth Harmonic

\[ l = \frac{7}{4} \lambda, \lambda = \frac{4}{7} l, f = \frac{7v}{4l} \]

Third Overtone, Seventh Harmonic

\[ l = \frac{n}{2} \lambda, \lambda = \frac{2l}{n}, f = \frac{n v}{2l} \]

\[ l = \frac{4l}{2n-1}, \lambda = \frac{4l}{2n-1}, f = \frac{(2n-1) v}{4l} \]

Making Sound - Wind Instruments

Musical applications of open and closed pipes

A flaming tube

Ruben's tube

We can generate pure tones with this Online tuning fork

Or play music from Pandora
Beats

Beats occur when two waves with frequencies close to one another interfere.

If the two waves are described by

\[ D_1 = A \sin 2\pi f_1 t \]

and

\[ D_2 = A \sin 2\pi f_2 t \]

\[ D = D_1 + D_2 \]

Using \( \sin \theta_1 + \sin \theta_2 = 2 \sin \frac{1}{2} (\theta_1 + \theta_2) \cos \frac{1}{2} (\theta_1 - \theta_2) \)

\[ D = 2A \cos 2\pi (\frac{f_1-f_2}{2})t \sin 2\pi (\frac{f_1+f_2}{2})t \]

A maximum in the amplitude is heard whenever \( \cos 2\pi (\frac{f_1-f_2}{2})t \) is equal to 1 or -1. Which gives a beat frequency of \( |f_1 - f_2| \).