Lecture 28 - 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/

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

$D = A\sin(kx - \omega t)$

im.png

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

$\Delta P = -B\frac{\Delta V}{V} = -B\frac{Area(D_2 - D_1)}{Area(x_2 - x_1)}$ which in the limit of $\Delta x \to 0$ is $\Delta P = -B\frac{\partial D}{\partial x}$

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

Displacement and pressure

$D = A\sin(kx - \omega t)$

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

ΔP 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 time as intense sounds only twice as loud to us. The sound level β 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 $I_0 = 1.0 \times 10^{-12}\mathrm{W/m^2}$

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

$kl = \frac{2\pi l}{\lambda} = \pi, 2\pi, 3\pi, 4\pi..$ etc.

or $\lambda = 2l, l, 2/3l, l/2, ..$ etc.

$f = \frac{v}{\lambda} = \frac{v}{2l}, \frac{v}{l}, \frac{3v}{2l}, 2vl, ..$ etc.

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

$\lambda = \frac{2l}{n}$ and $f = v\frac{n}{2l}$

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

im.png

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. im.png

Making Sound - Wind Instruments

Musical applications of open and closed pipes

A flaming tube

Ruben's tube, invented by Heinrich Rubens in 1905, like the Shive Wave Machine, is really only useful at demonstrating wave concepts. But it's very good at that!

im.png

To understand why the flames are higher where the pressure varies more we need to realize that the velocity at which gas flows out is proportional to the square root of the pressure difference. This comes from Bernoulli's principle.

It's worth noting that as the speed of sound is $v = \sqrt{\frac{B}{\rho}}$ and the density ρ can be approximated as the propane pressure the standing wave frequencies depend on the propane pressure and will not be the same as the frequencies when the tube is just full of air at external pressure.

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 $|f_1 - f_2|$.

Can you hear the beat?

Typically when two tones are seperated by less than about 30-40Hz we hear beating, if the separation is more than that they tend to sound like to different tones. (You can try a similar experiment at a higher frequency at Beats from Physclips).

Beats Generator

im.png

Quiz

A piano tuner uses a 512-Hz tuning fork to tune a piano. He strikes the fork and hits a key on the piano and hears a beat frequency of 5 Hz. He tightens the string of the piano, and repeats the procedure. Once again he hears a beat frequency of 5 Hz. What happened?

In [ ]:

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l=1.5
f =
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