Fundamentals of Musical Acoustics

What is sound?

air pressure

time
These variations in air pressure over time can be decomposed into sine waves with amplitude and frequency.
Simple Harmonic Motion
(Makes sine waves)

Sinusoids

\[ y = \sin \theta \]
\[ x = \cos \theta \]
$a = \sin(t)$

$a = \cos(t)$

Amplitude

$a = A \sin(t)$
Frequency

How frequently does the sin/cos complete a whole cycle?
**Frequency**

1 cycle \[ 2\pi \]

1 cycle / sec. \[ 2\pi / \text{sec.} \]

\( f \) cycles / sec. \( f \cdot 2\pi / \text{sec.} \)
Radian Frequency

\[ \omega = 2\pi f \]

\[ f = \frac{\omega}{2\pi} \]

\[ y = A \cos (2\pi ft) \]

\[ x = A \cos (2\pi ft) \]
a = A \sin(2\pi ft)

a = A \cos(2\pi ft)

\[ a = A \sin(2\pi ft) \]

\[ a = A \cos(2\pi ft) \]

\[ f = \frac{1}{T} \]

\[ T = \text{period} \]

fraction of a second in which one cycle repeats

Period
Phase

\[ a = A \sin(2\pi ft + \phi) \]

\[ \phi = \frac{2\pi}{T} \text{ phase} \]

\[ f = \frac{1}{T} \]
Two Domains of Description

Time

Frequency

Frequency Domain Representation

\[ a = A \sin (2\pi f + \phi) \]
Frequency Domain

What can I hear?

Fletcher & Munson

Modes of Vibration

N = node
Joseph Fourier (1768 - 1830)

Periodic function
\[ f(t) = f(t + T) \]

Integral multiple harmonics
\[ f(t) = \sum_{n=0}^{\infty} A_n \sin(2\pi n Ft + \phi_n) \]

Harmonic Series

Fundamental

Modes of Vibration
Superposition of Harmonics

Ongoing Superposition / Interference

constructive
Identical Frequencies

Different Frequencies

destructive

180° out of phase
inharmonic

harmonic

Resonance

$\phi$

behind
Resonance

Input: Amplitude

Output: Amplitude

\[ Q = \frac{f_0}{\Delta f} \]

High Q

Low Q

\[ \Delta f = f - f_0 \]
FIG. 10.14
Input admittance (driving point mobility) of a Guarneri violin driven on the bass bar side (Alonso Moral and Jansson, 1982b)

**Time Domain**

**Real world Sounds**

FIGURE 1.12. A waveform plot of the spoken word “shut.” A noise-like (aperiodic) portion for the “sh” sound precedes the more pitched “u” sound, while the “t” is transient.
**Ongoing Spectral Change**

- Temporal envelope
- Spectral envelope
- Formants
- Envelopes
- Attack, sustain, decay
- Pressure wave
- Fourier analysis at four time points
- Amplitude envelopes
3-D graphs

loud
soft
low
high
start
stop