OSHER LIFELONG LEARNING INSTITUTE

Sound of Music

How It Works

Session 1

Building Blocks

This pdf handout does not contain the animations or sounds of the original presentation.

OLLI at Illinois

Spring 2020

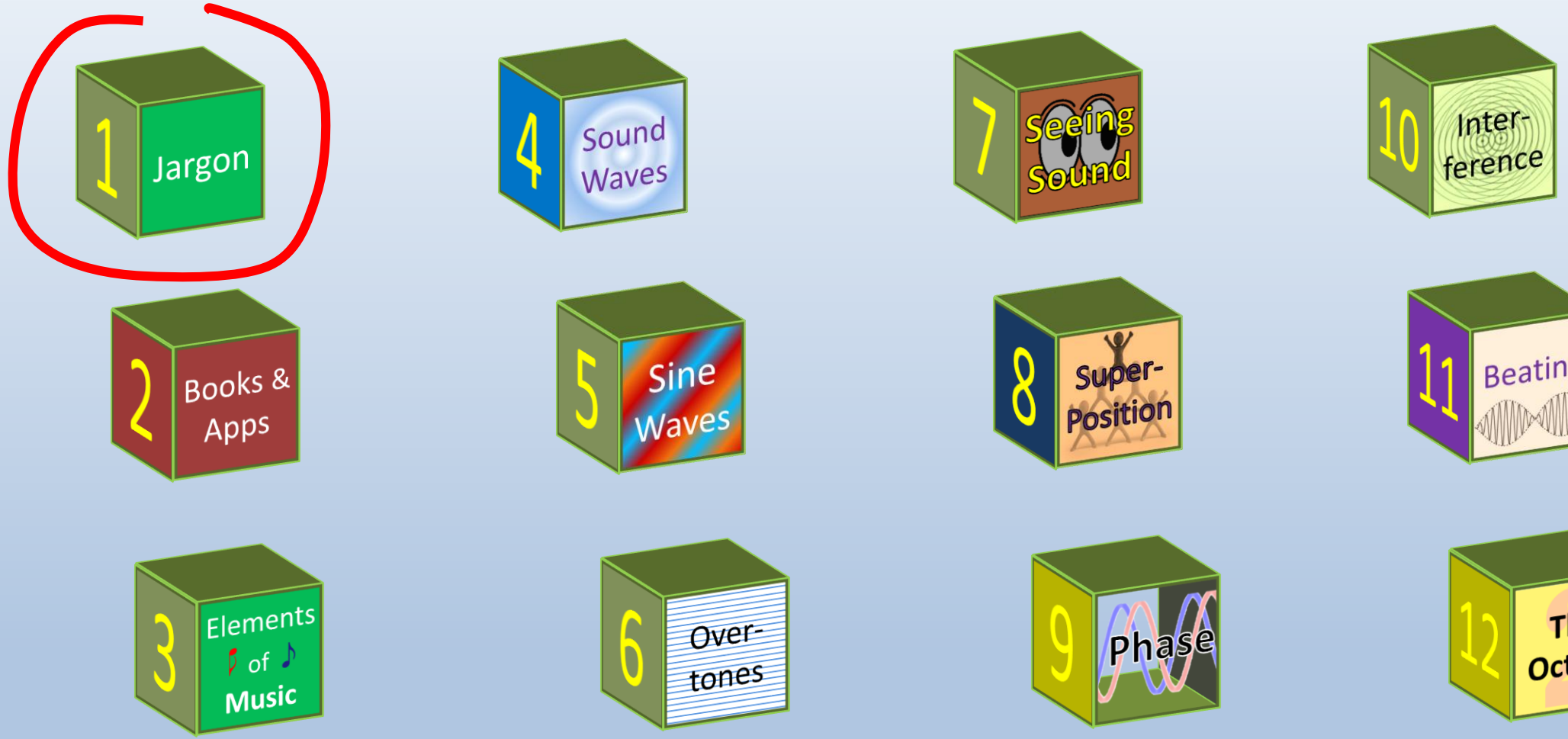
D. H. Tracy

DavidHTracy@gmail.com

Course Outline

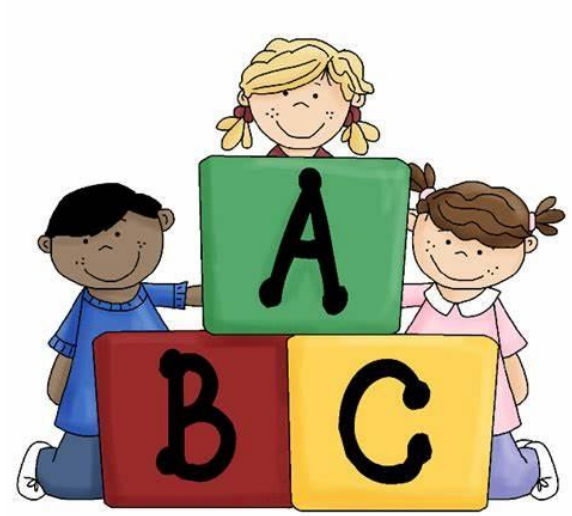
1. Building Blocks: Some basic concepts
2. Resonance: Building Sounds
3. Hearing and the Ear
4. Musical Scales
5. Musical Instruments
6. Singing and Musical Notation
7. Harmony and Dissonance; Chords
8. Combining the Elements of Music

Session 1 Outline: Building Blocks



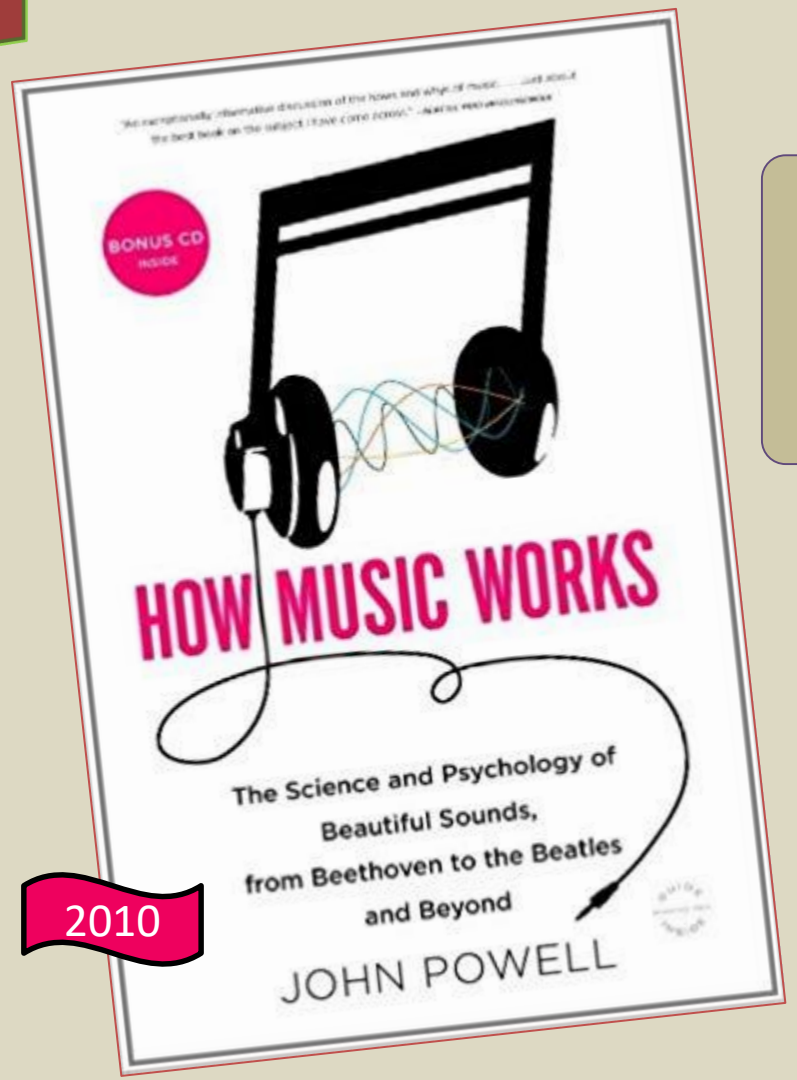
Jargon

- We'll try to *avoid* Jargon (as much as possible)
- Music has a very long history
  - Vocabulary, concepts, notation, even instruments have deep roots
  - Lots of baggage…Legacy terminology
  - Potential for obscuration or confusion!

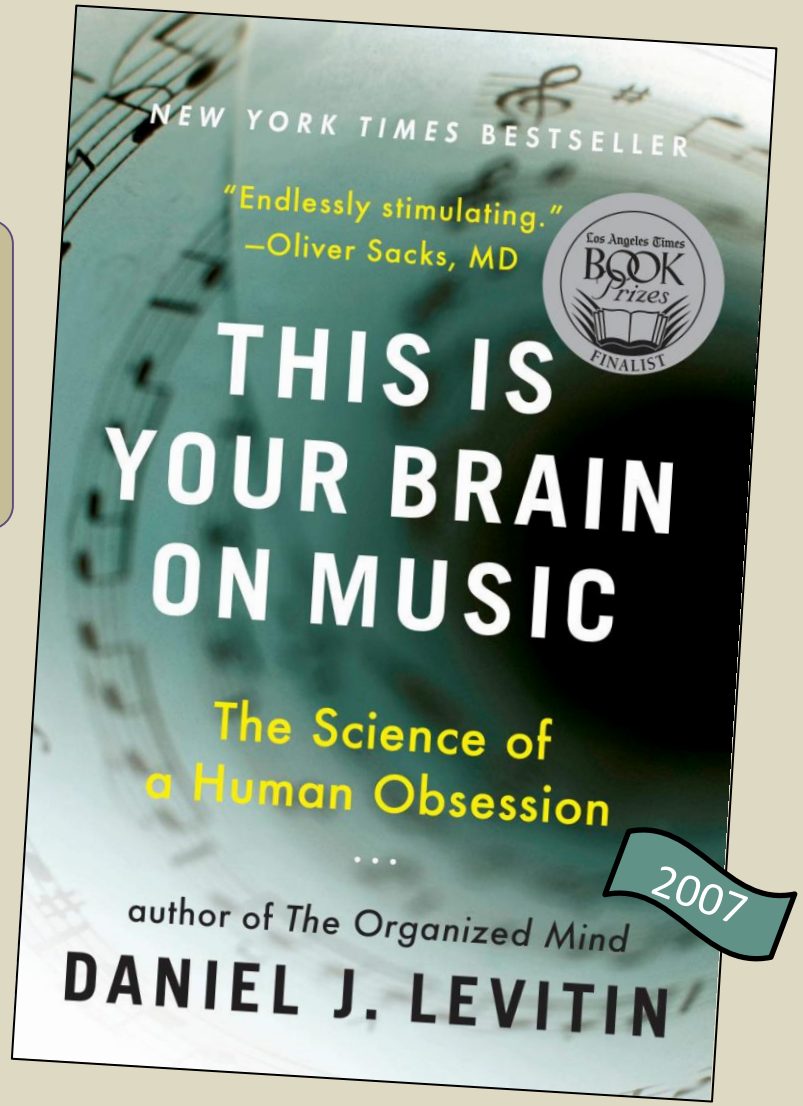


Building Blocks

Books

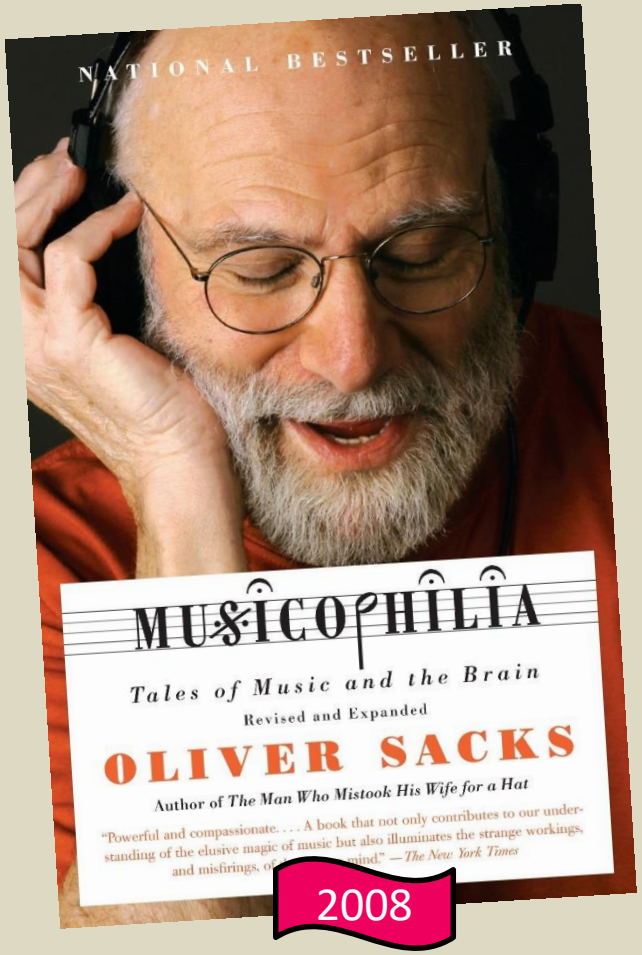


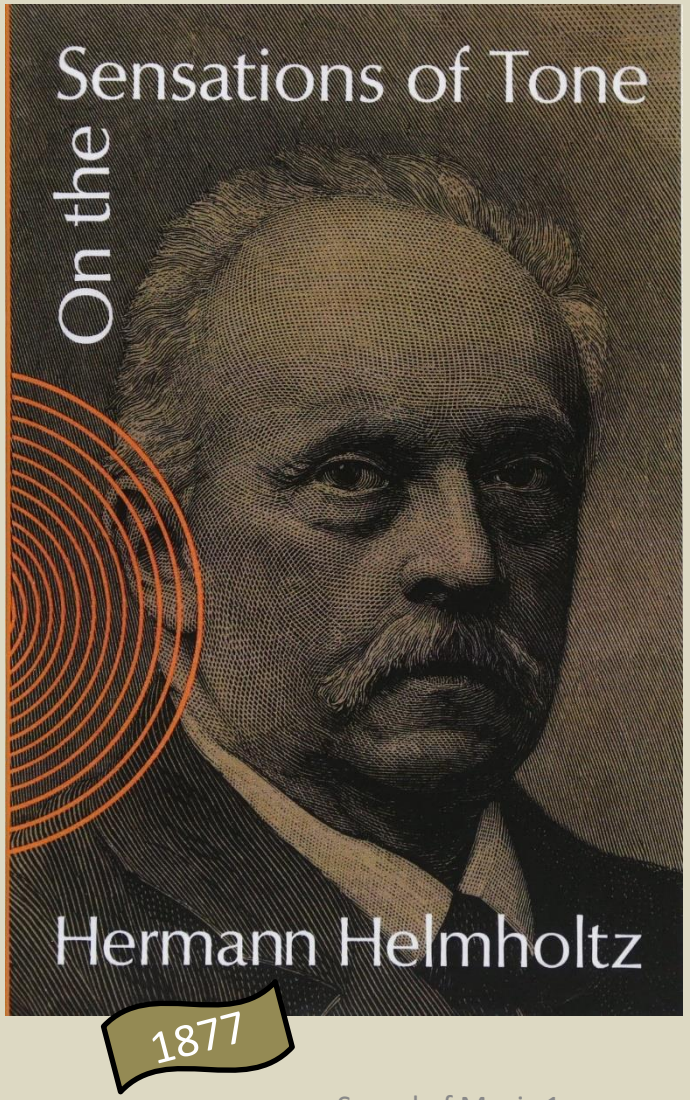
Both Authors are
Scientists
and
Musicians

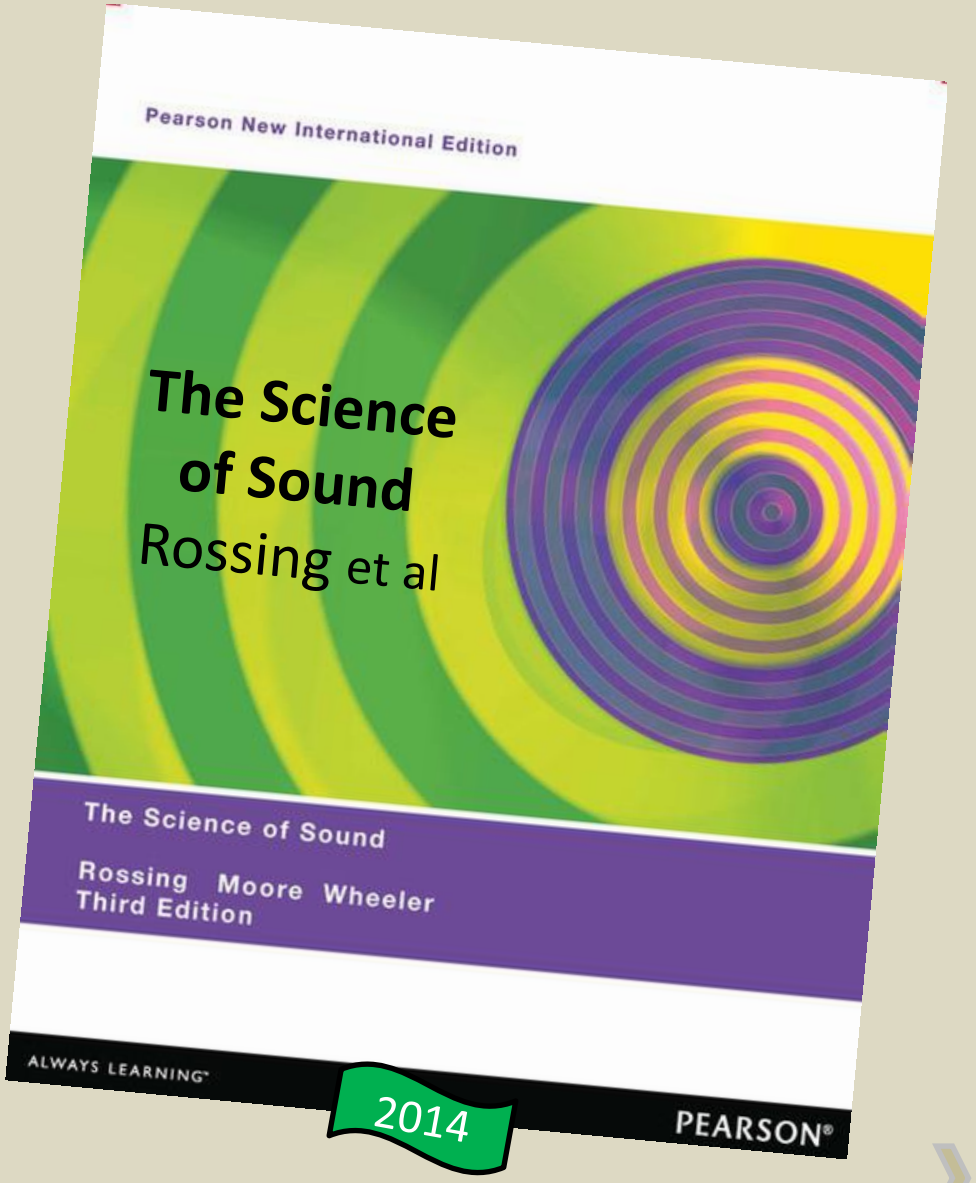



2
Books &
Apps

More Books

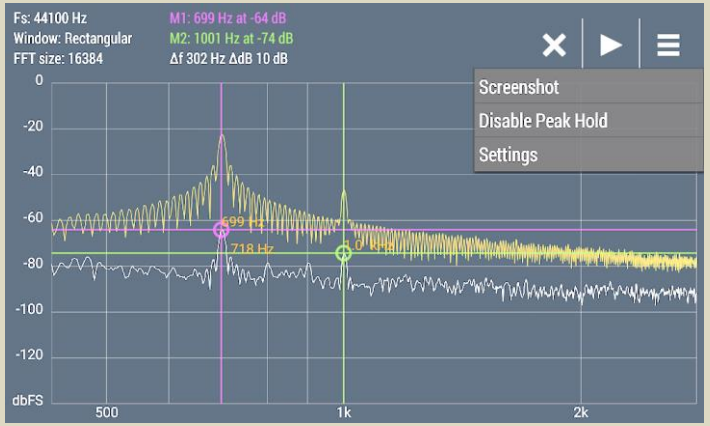

NATIONAL BESTSELLER
MUSICOPHILIA
Tales of Music and the Brain
Revised and Expanded
OLIVER SACKS
Author of The Man Who Mistook His Wife for a Hat
"Powerful and compassionate. . . . A book that not only contributes to our understanding of the elusive magic of music but also illuminates the strange workings, and misfirings, of . . . mind." —The New York Times
2008


On the Sensations of Tone
Hermann Helmholtz
1877


Pearson New International Edition
The Science of Sound
Rossing et al
The Science of Sound
Rossing Moore Wheeler
Third Edition
ALWAYS LEARNING
PEARSON
2014

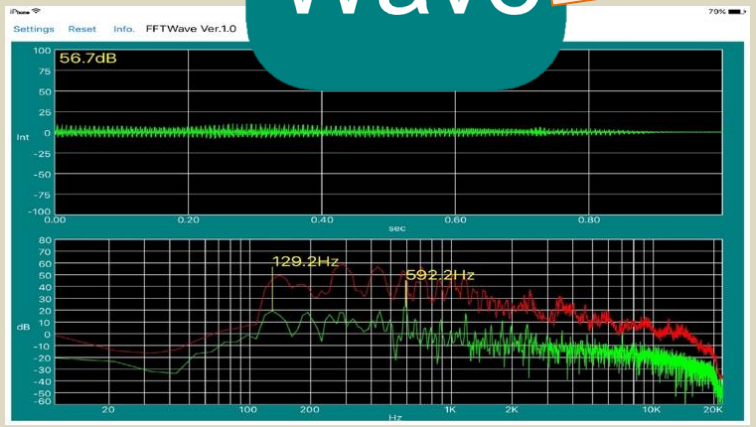
SmartPhone Apps

Advanced Spectrum Analyzer Pro

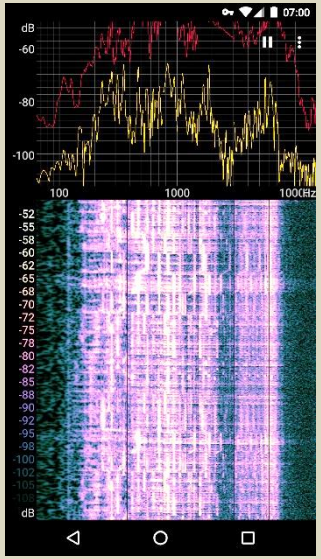


FFT Wave

Free for Android *and* iOS



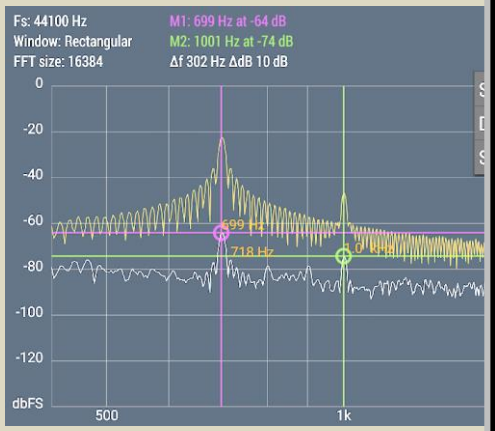
Spectroid



Hz

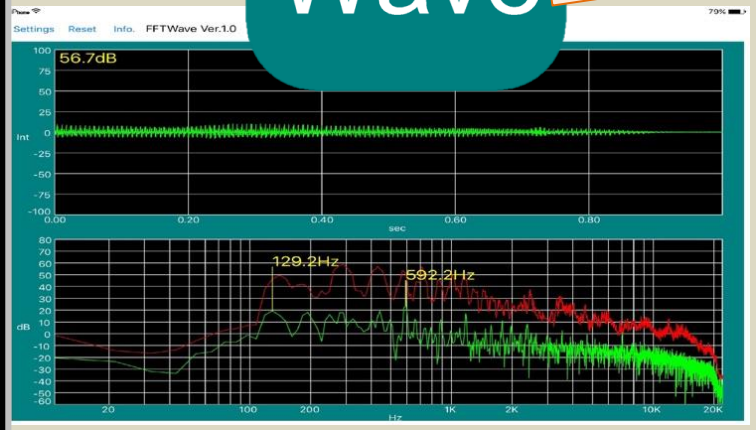
SmartPhone Apps

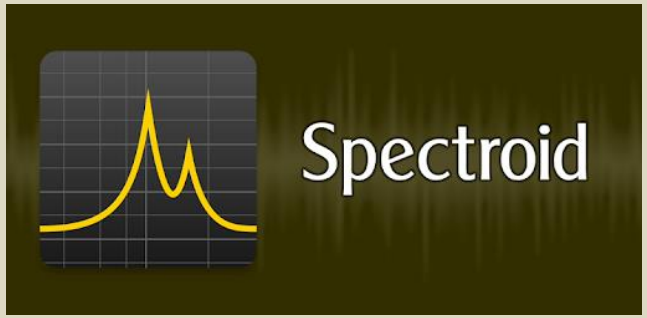
Advanced Spectrum Analyzer Pro

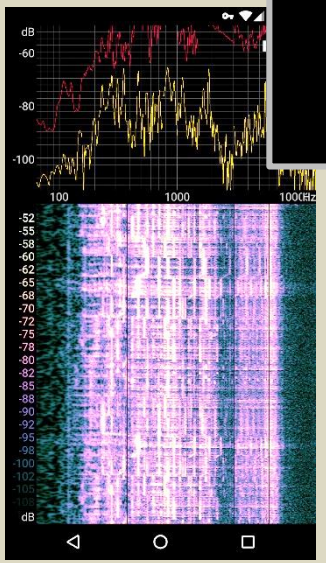


FFT Wave

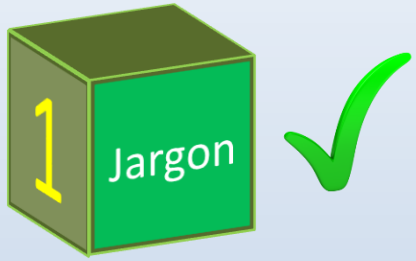
Free for Android *and* iOS

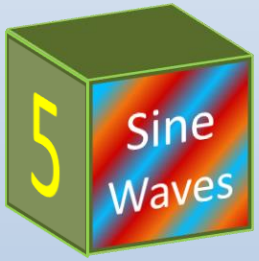


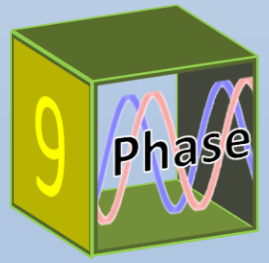




Building Blocks





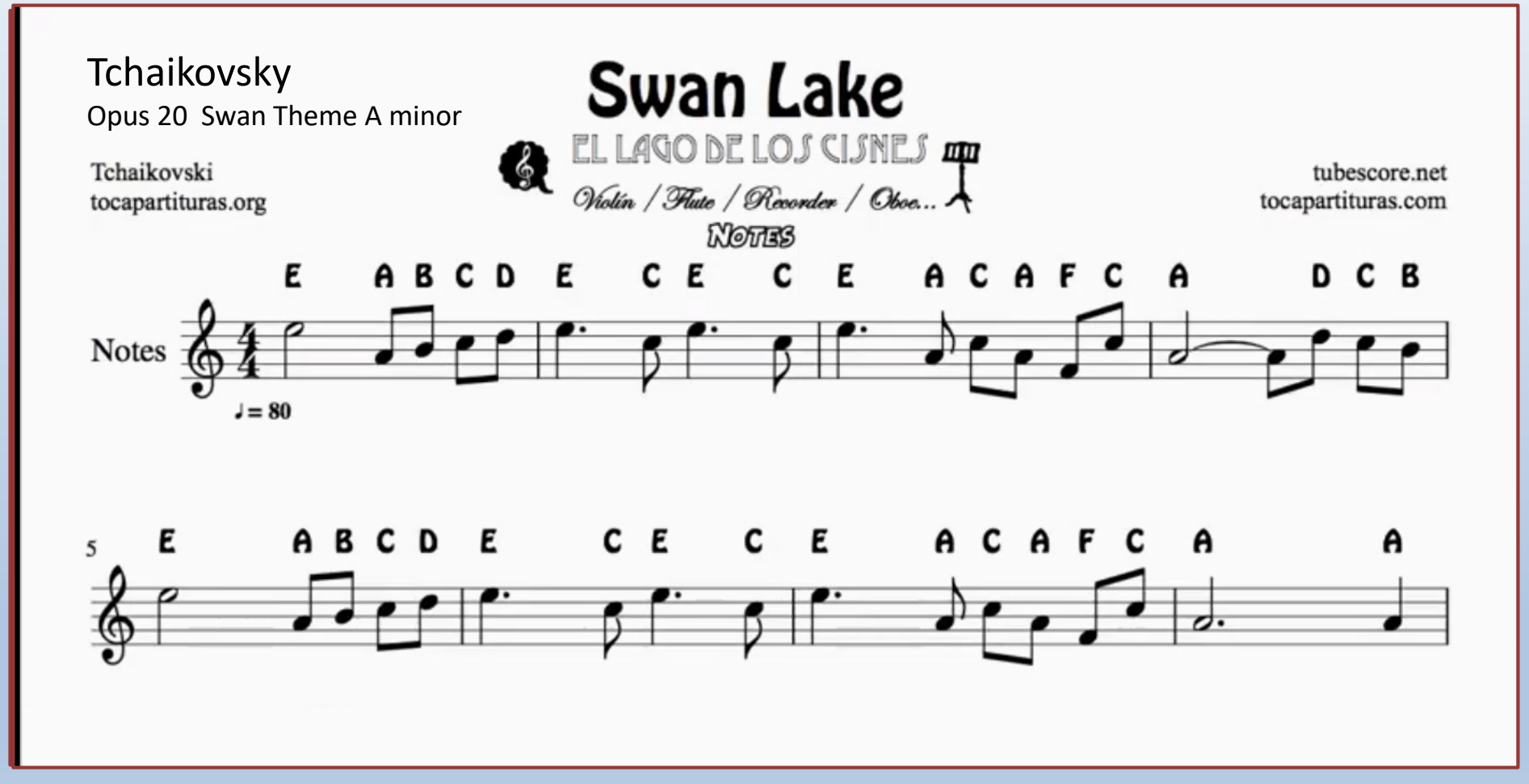


Elements of Music

- Rhythm

Elements of Music

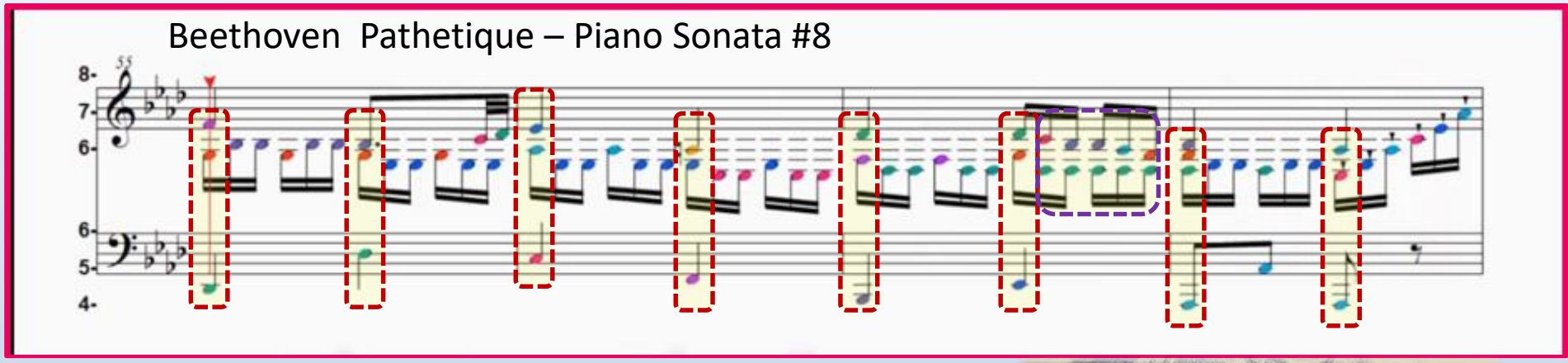
- Rhythm
- Melody



Tchaikovsky Swan Lake Easy Notes Sheet Music for Violin Flute Oboe

Elements of Music

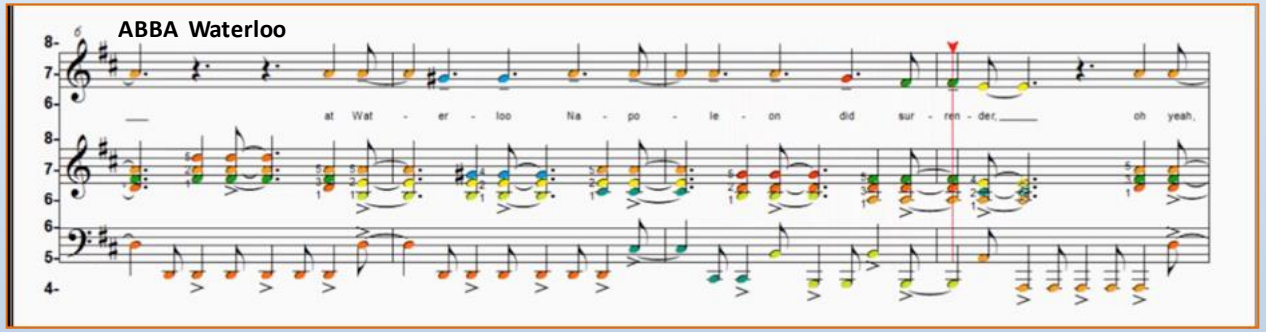
- Rhythm
- Melody
- Harmony

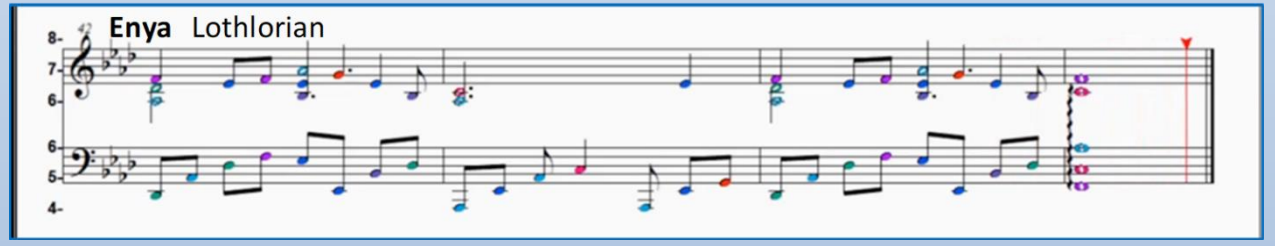


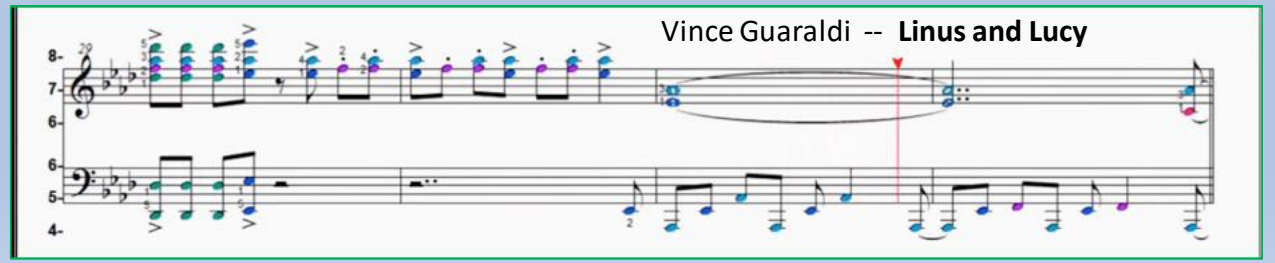
Harmony refers to notes played *simultaneously*

Elements of Music

- Rhythm
- Melody
- Harmony





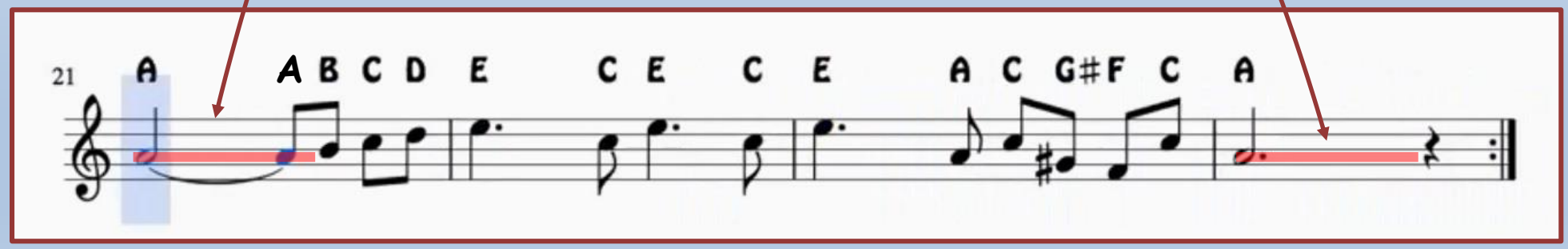


Elements of Music

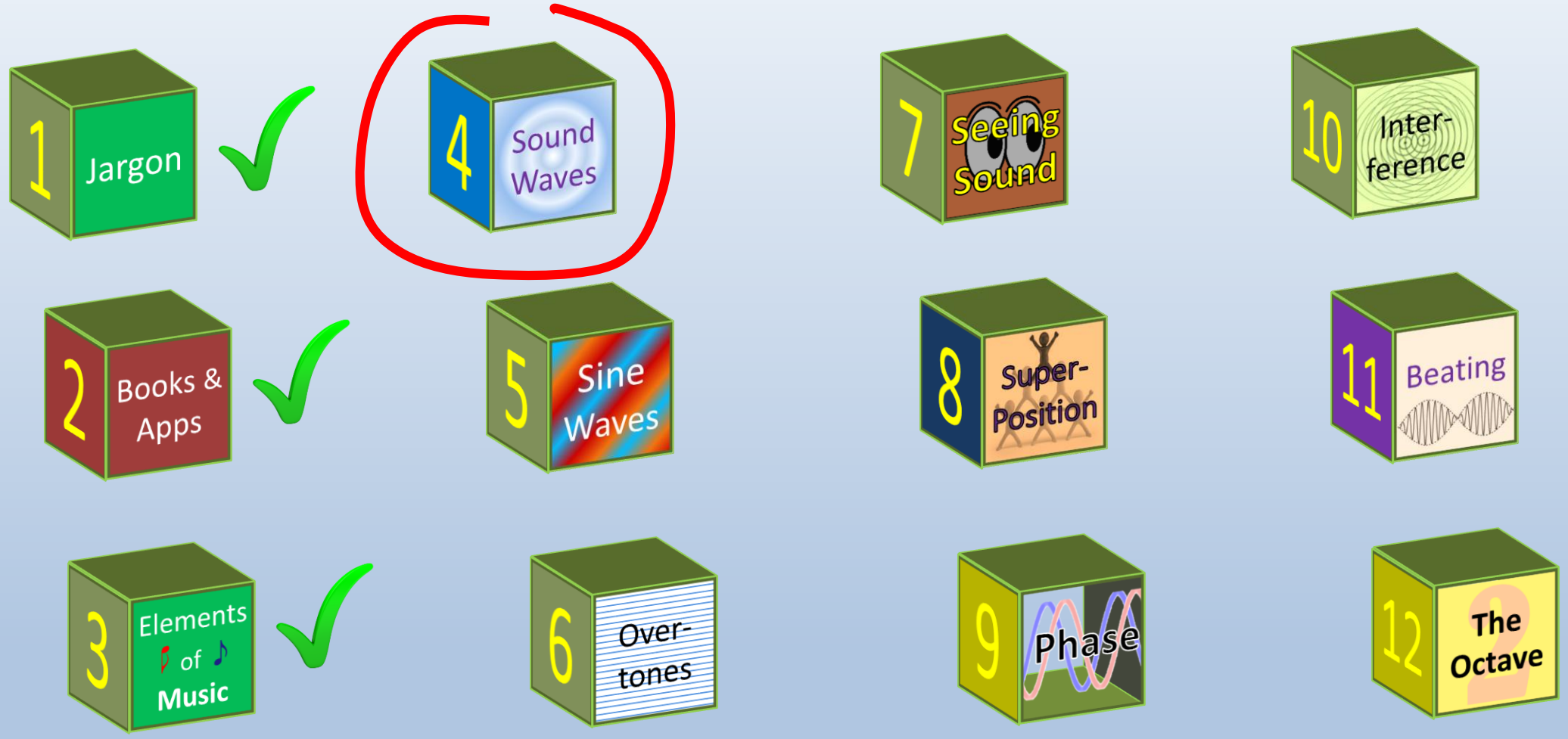
- Rhythm
- Melody
- Harmony
- Tonality

Phrase starts at pitch A, then eventually returns "home" to A

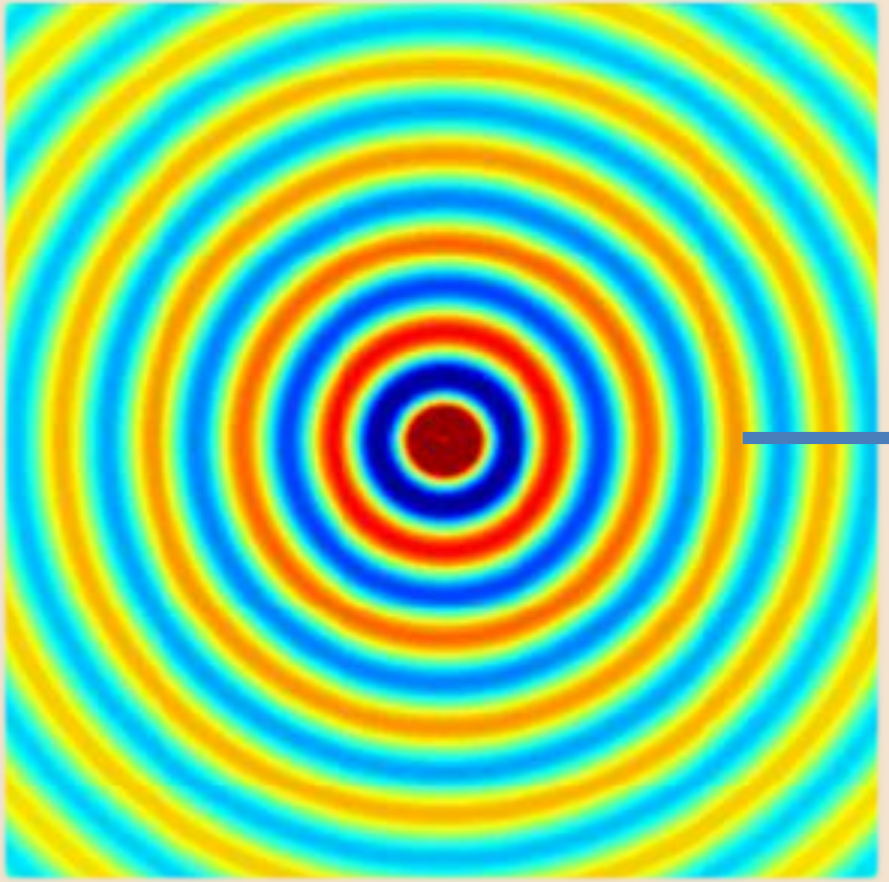
Tchaikovsky: Swan Lake Theme (A minor)



Building Blocks



Sound Waves in Air



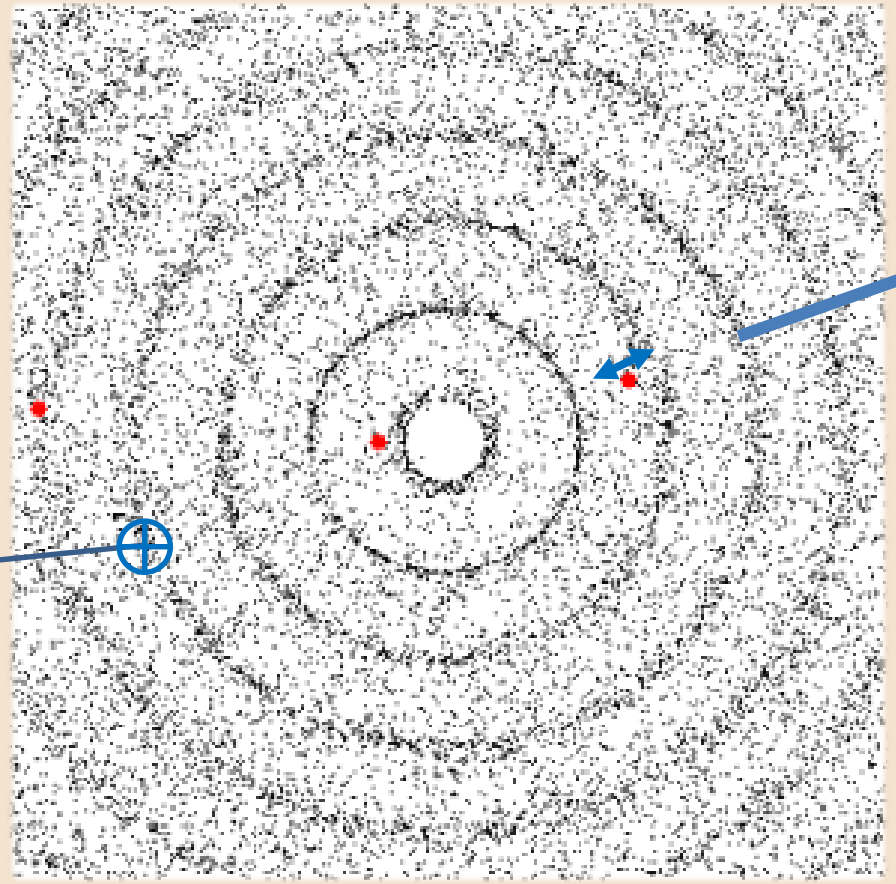
Velocity:

1000 ft/sec
(300 m/s)

Sound Waves in Air

Longitudinal Wave

Air molecules move *back and forth* along direction of wave propagation



Velocity:

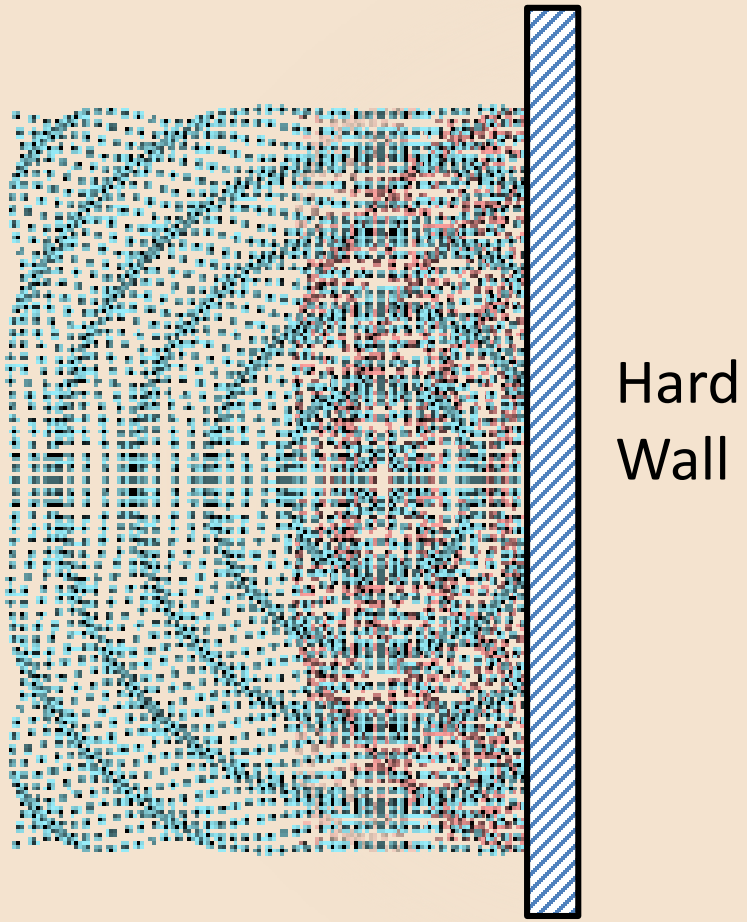
1000 ft/sec
(300 m/s)

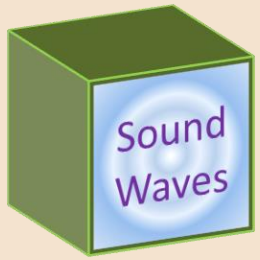
Air Pressure

bobs up and down as waves pass by any point

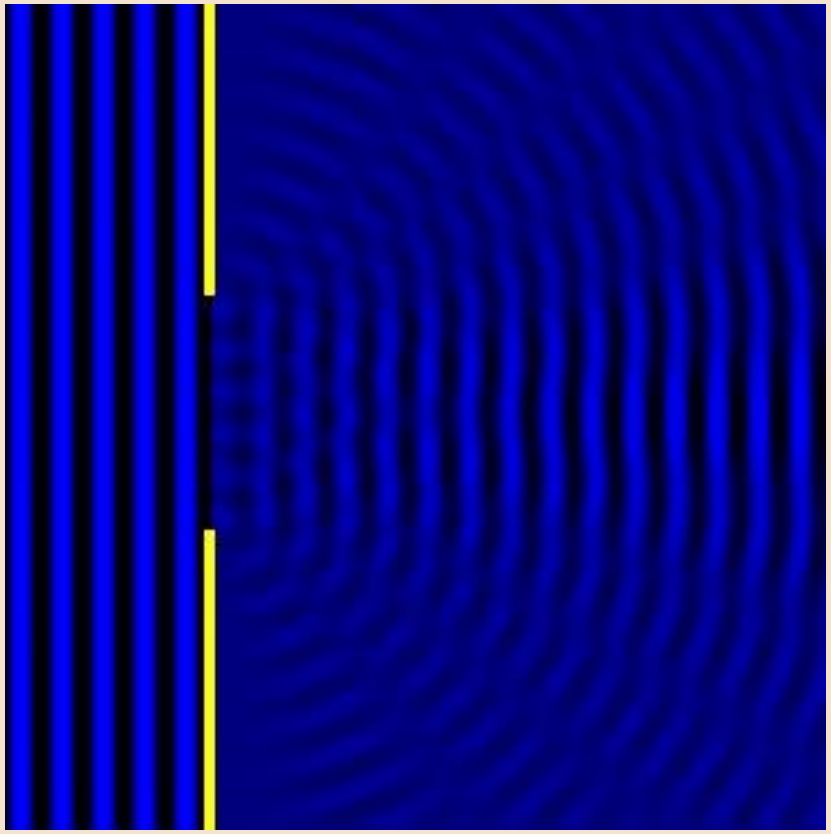
< 1 ***millionth*** of an atmosphere right now

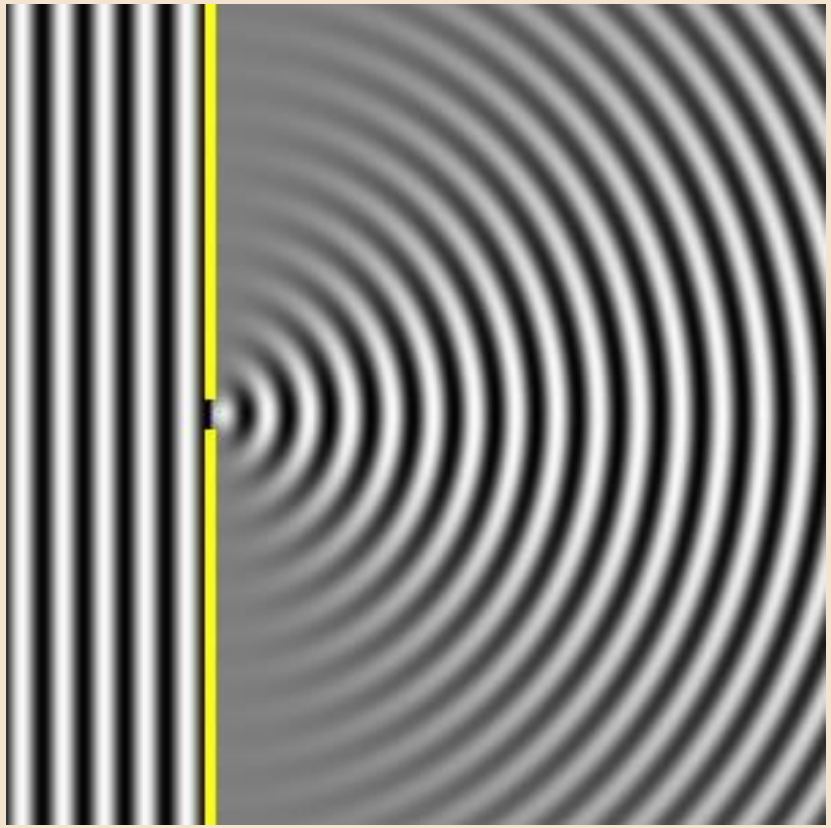
Sound Wave Reflection





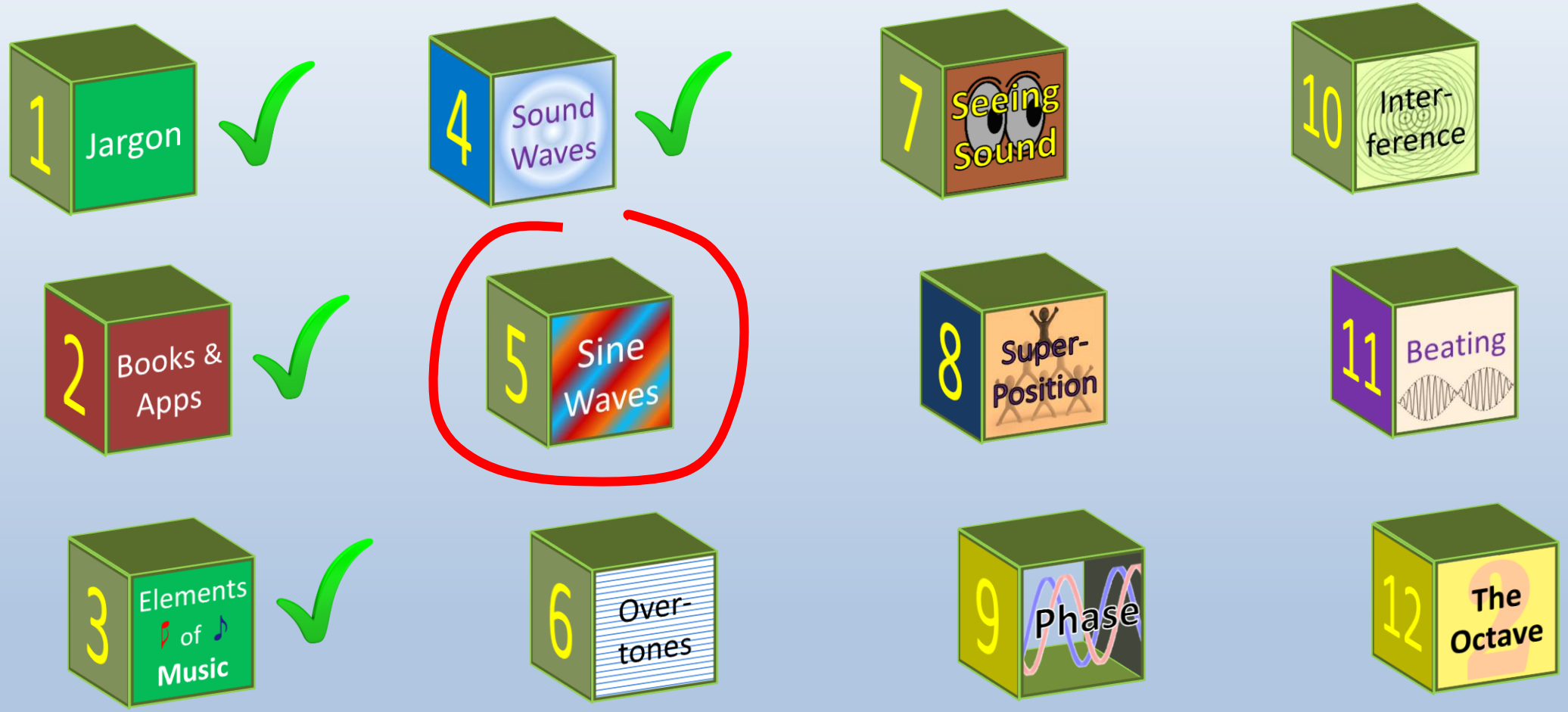
Sound Wave Diffraction

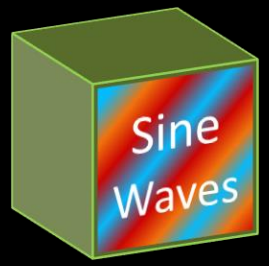




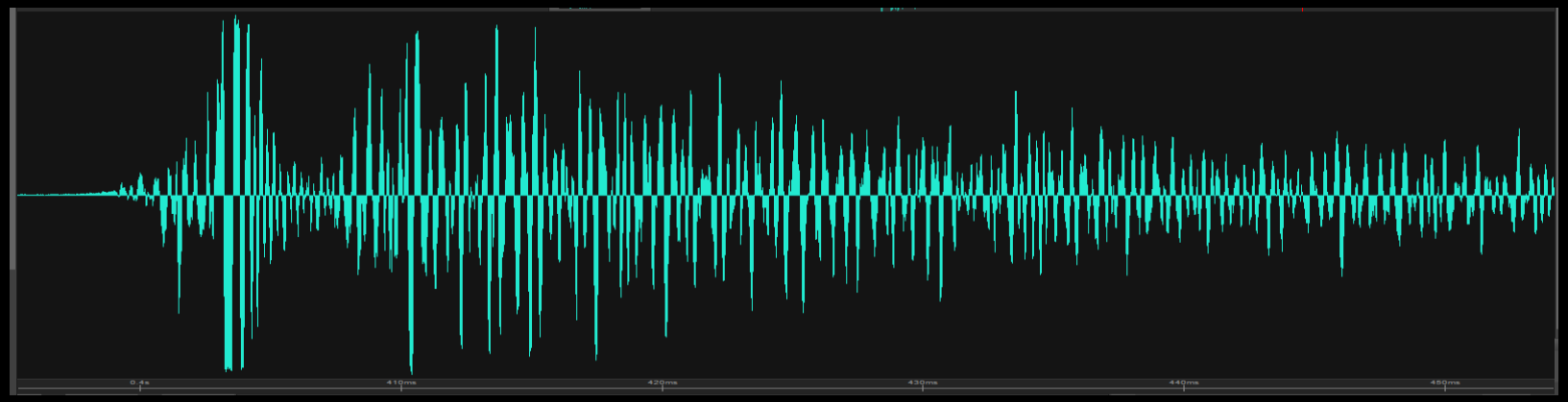
When hole is small compared to wavelength, more diffraction

Building Blocks

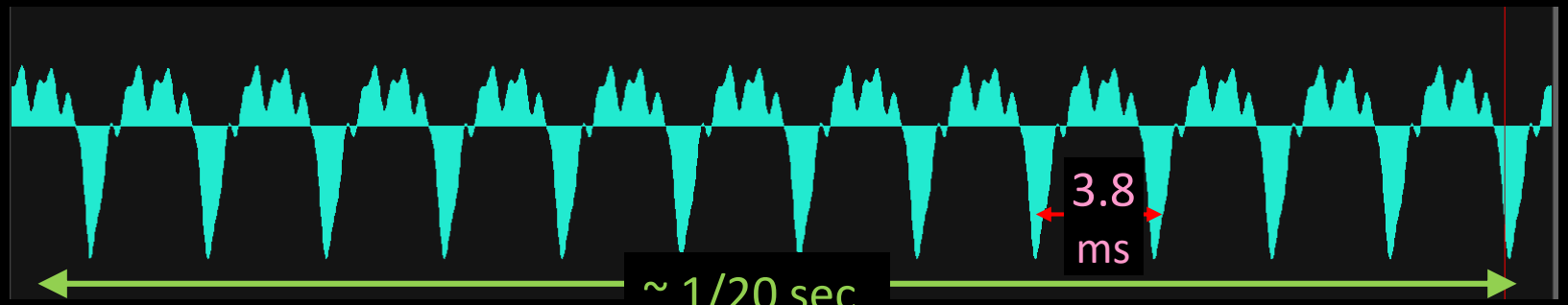




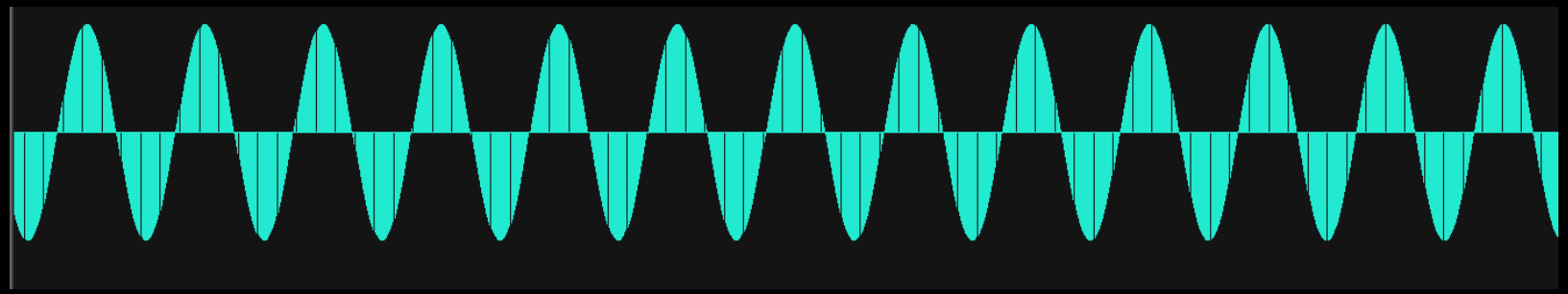
Types of Sound Waves



Non-periodic



Periodic



Sine

Sine Waves Characterized by Frequency

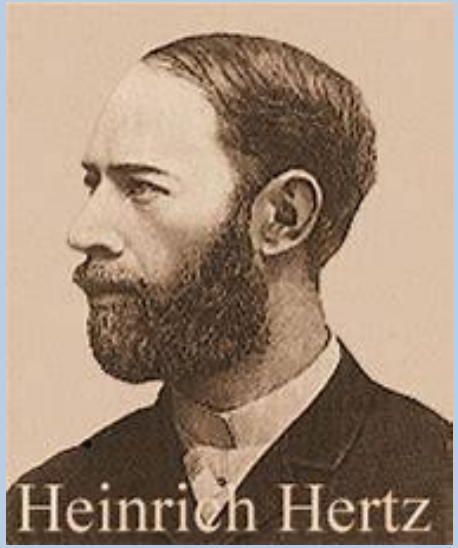
Frequency:

~~Vibrations per Second~~
~~or~~
~~Cycles Per Second~~

As of 1960, officially changed to

Hertz

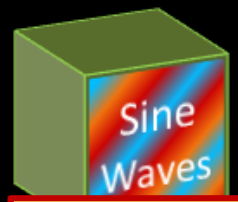
Hz

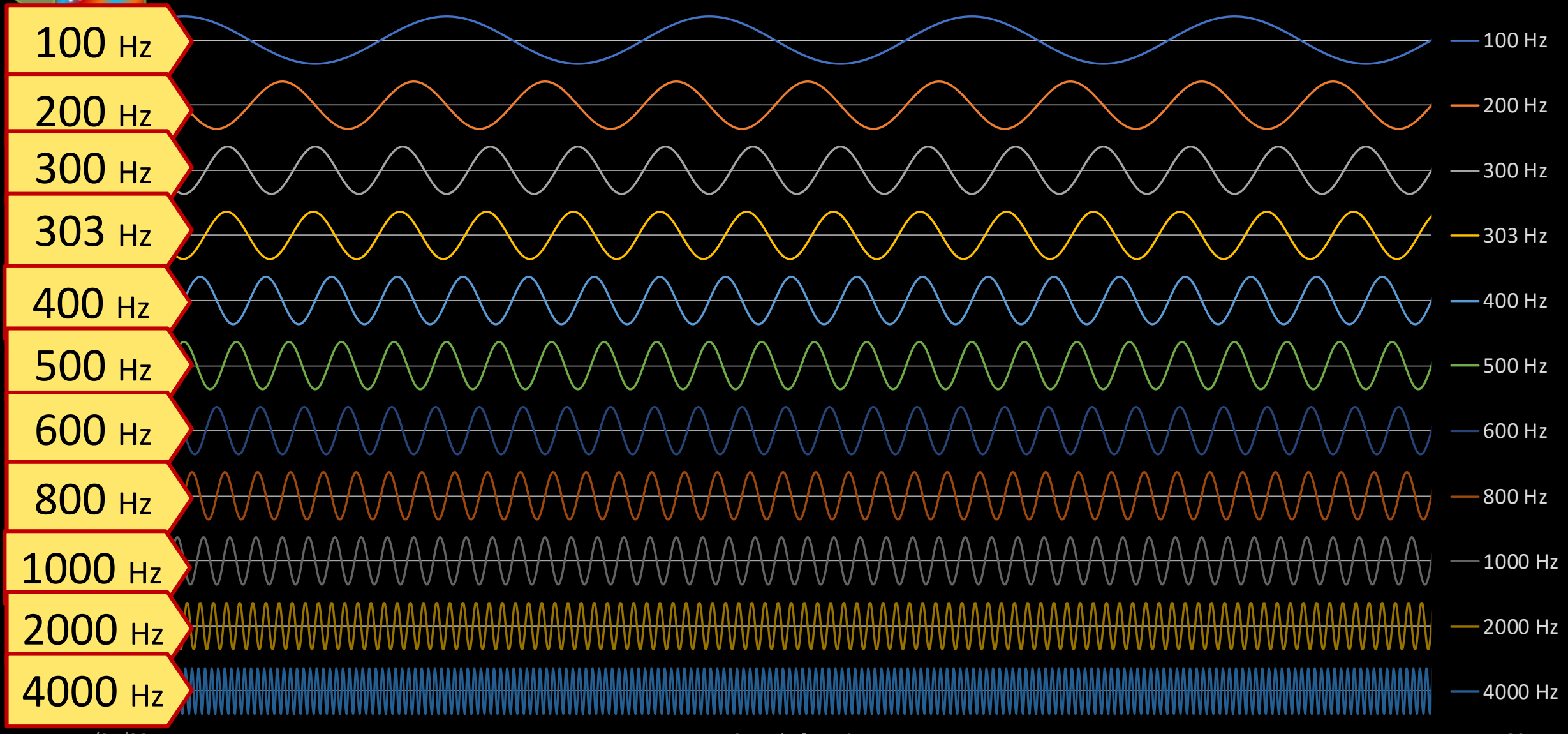


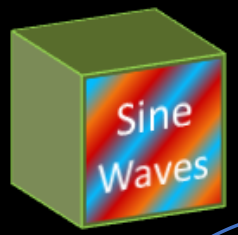
1857-1894

100 Hz
200 Hz
300 Hz
303 Hz
400 Hz
500 Hz
600 Hz
800 Hz
1000 Hz
2000 Hz
4000 Hz

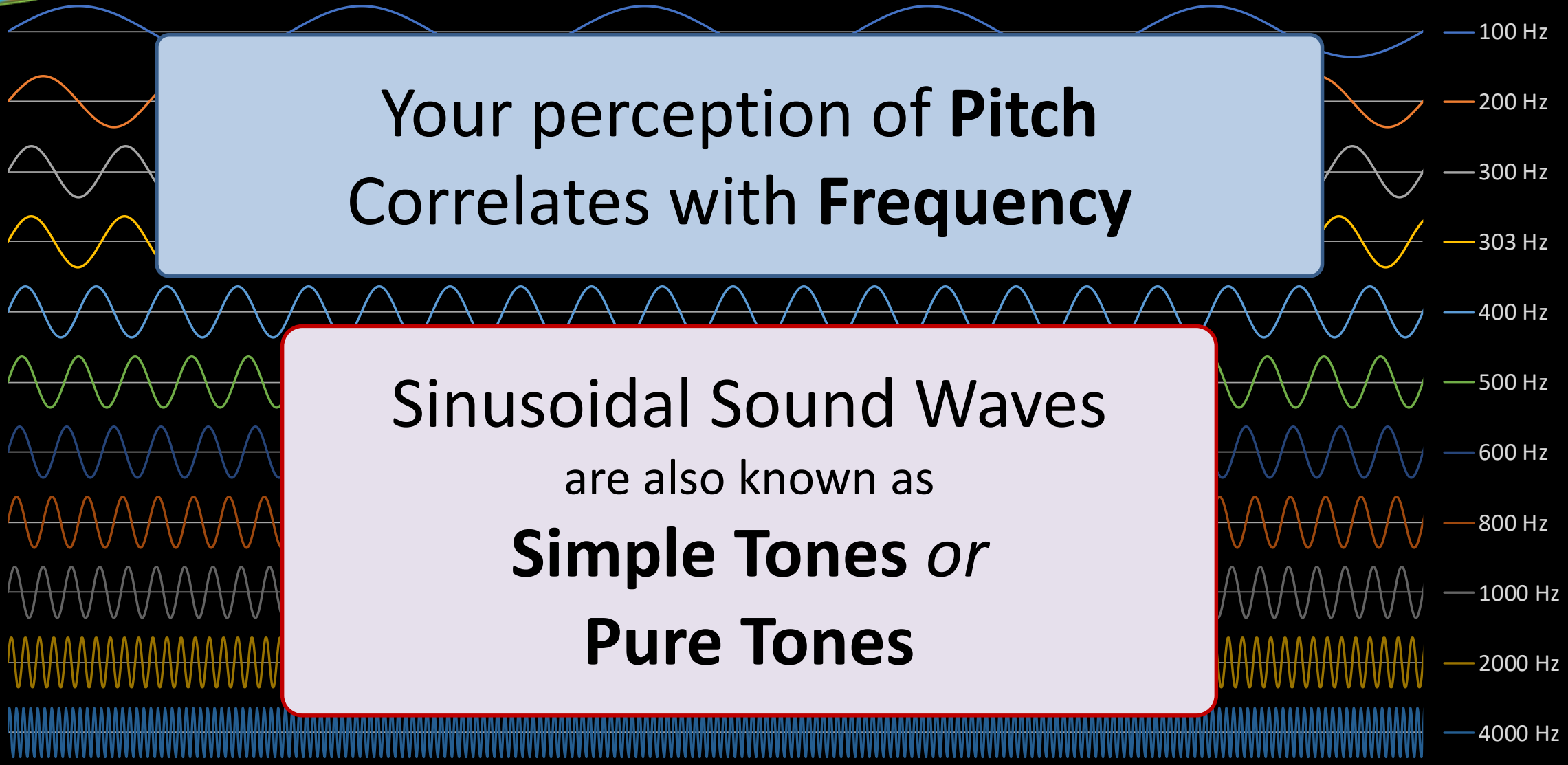
Sine Waves Characterized by Frequency







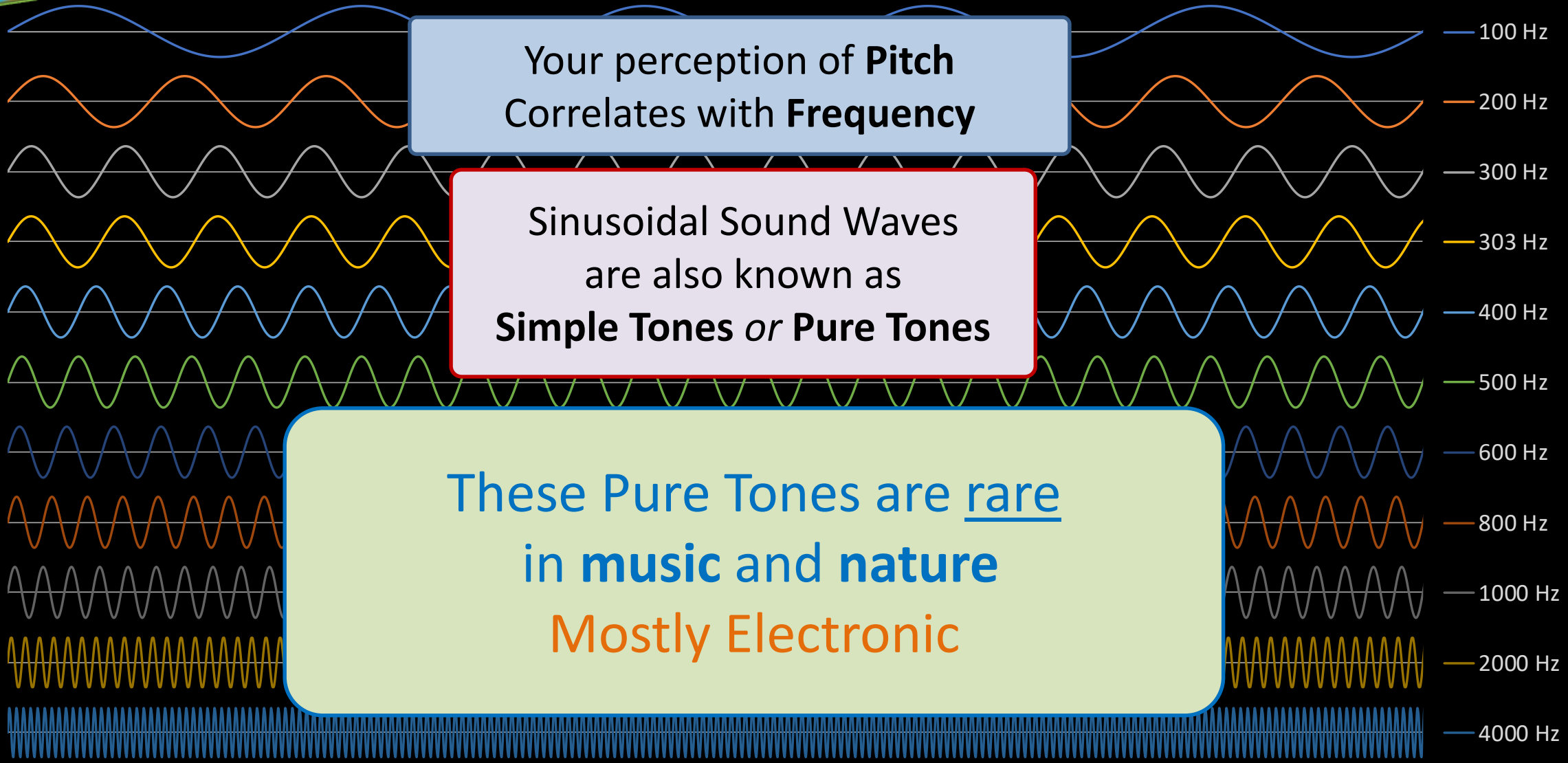
Sine Waves Characterized by Frequency



Your perception of **Pitch**
Correlates with **Frequency**

Sinusoidal Sound Waves
are also known as
Simple Tones *or*
Pure Tones

Sine Waves Characterized by Frequency

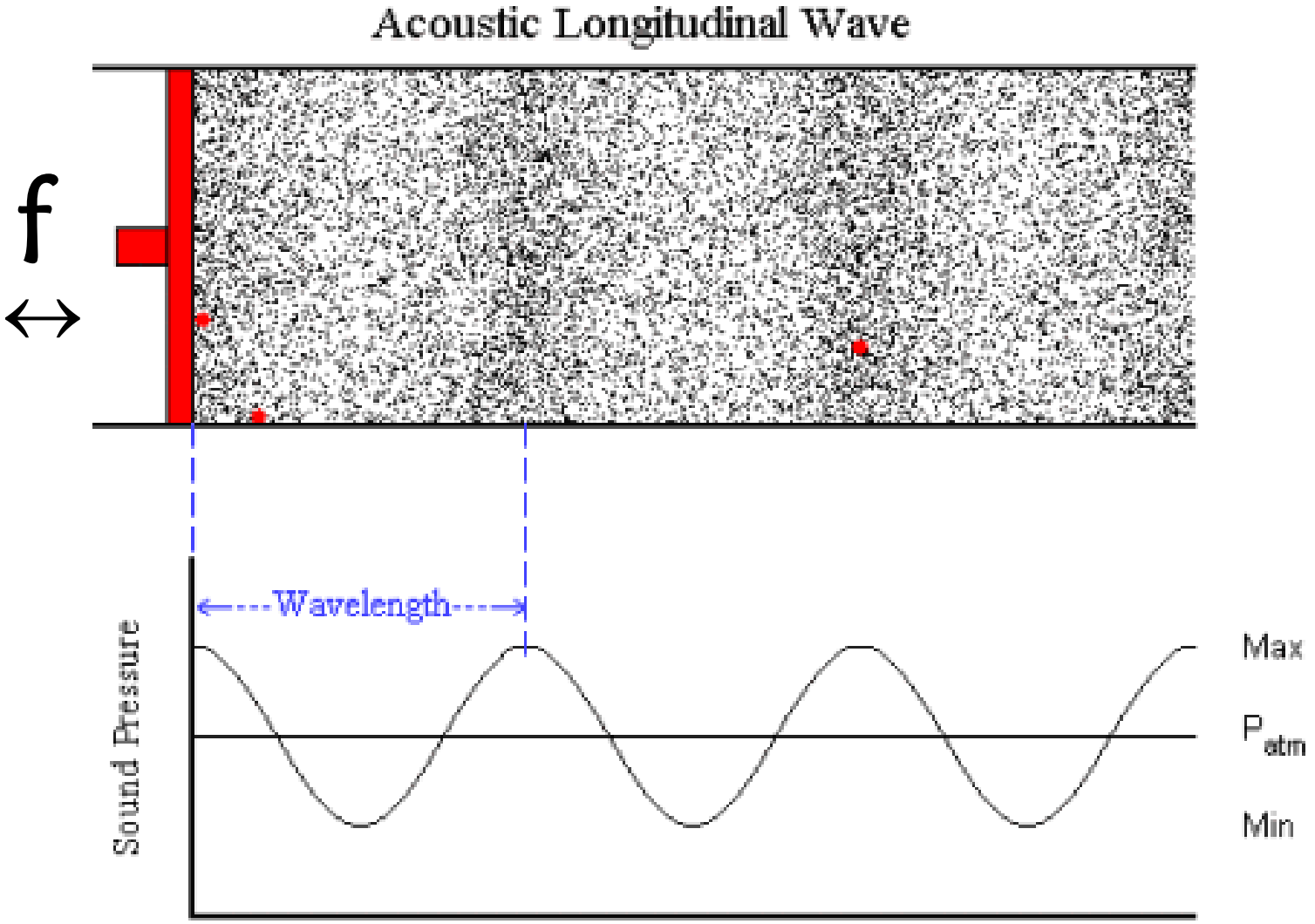


Your perception of **Pitch**
Correlates with **Frequency**

Sinusoidal Sound Waves
are also known as
Simple Tones *or* **Pure Tones**

These Pure Tones are rare
in **music** and **nature**
Mostly Electronic

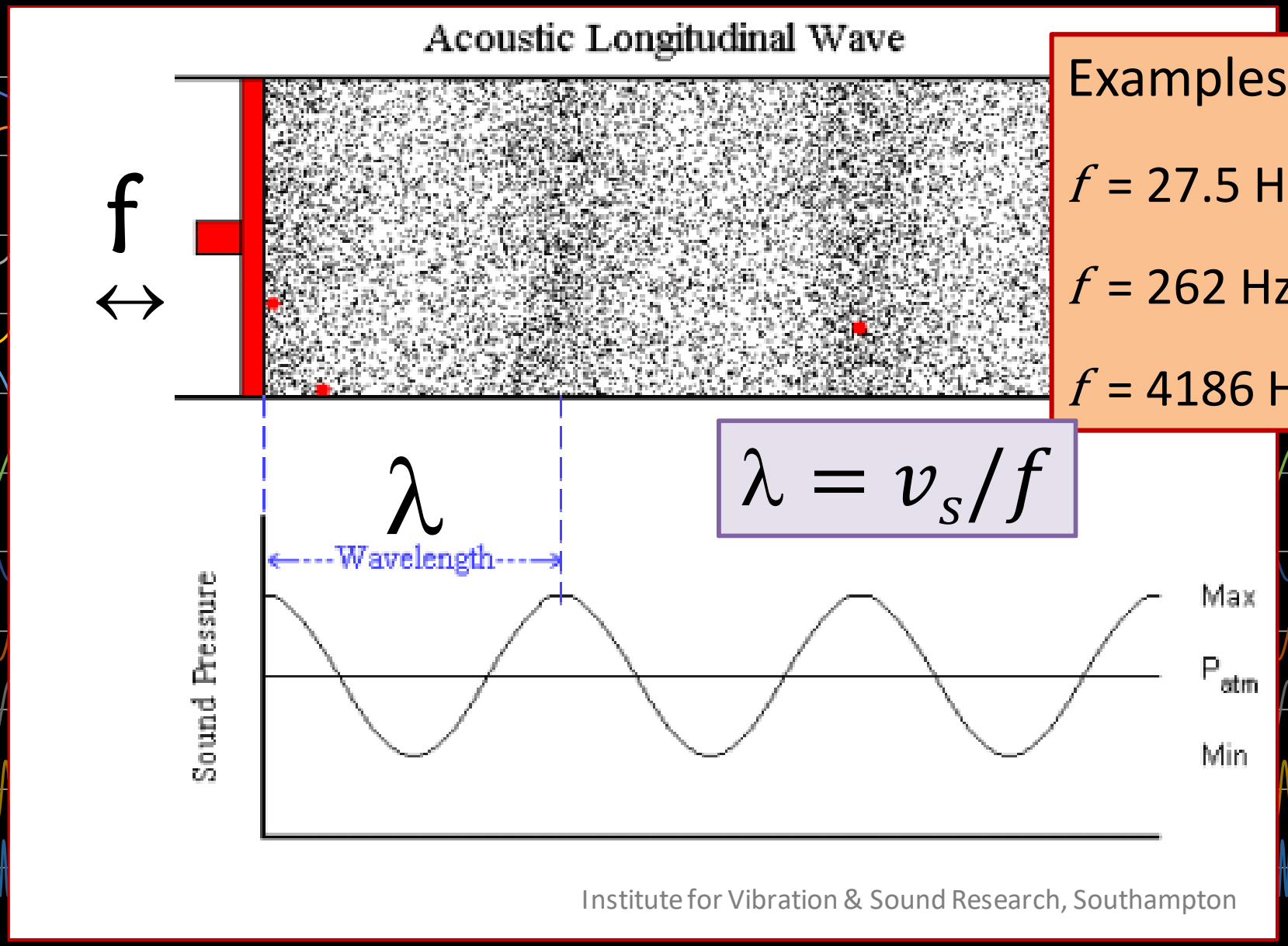
Sine Waves Characterized by Wavelength

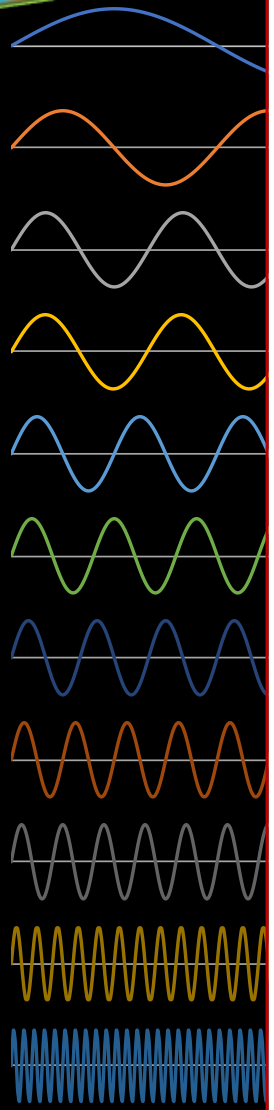


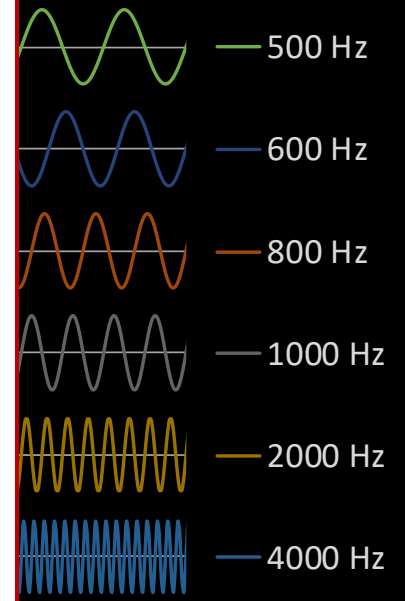
100 Hz
200 Hz
300 Hz
303 Hz
400 Hz
500 Hz
600 Hz
800 Hz
1000 Hz
2000 Hz
4000 Hz

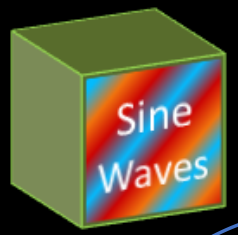
Institute for Vibration & Sound Research, Southampton

Sine Waves Characterized by Wavelength









Sine Waves Characterized by Wavelength

Examples:

f = 27.5 Hz $\lambda \approx$ **40** ft

f = 262 Hz $\lambda \approx$ **4** ft

f = 4186 Hz $\lambda \approx$ **3** in

500 Hz

600 Hz

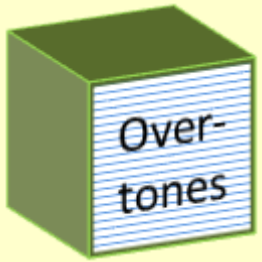
800 Hz

1000 Hz

2000 Hz

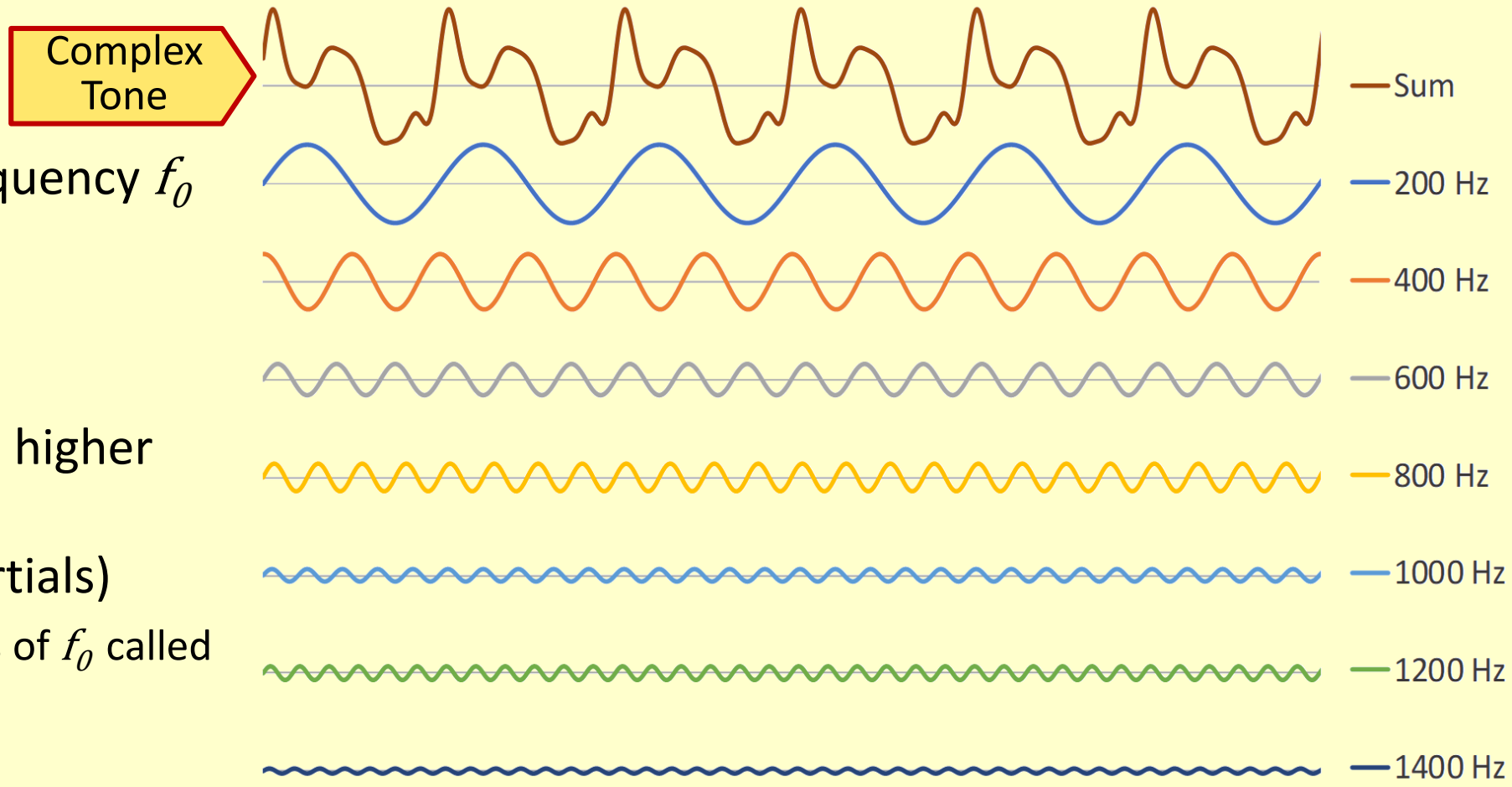
4000 Hz

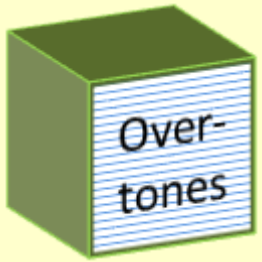
Building Blocks



Real Musical Notes are *not* Pure Sine Waves

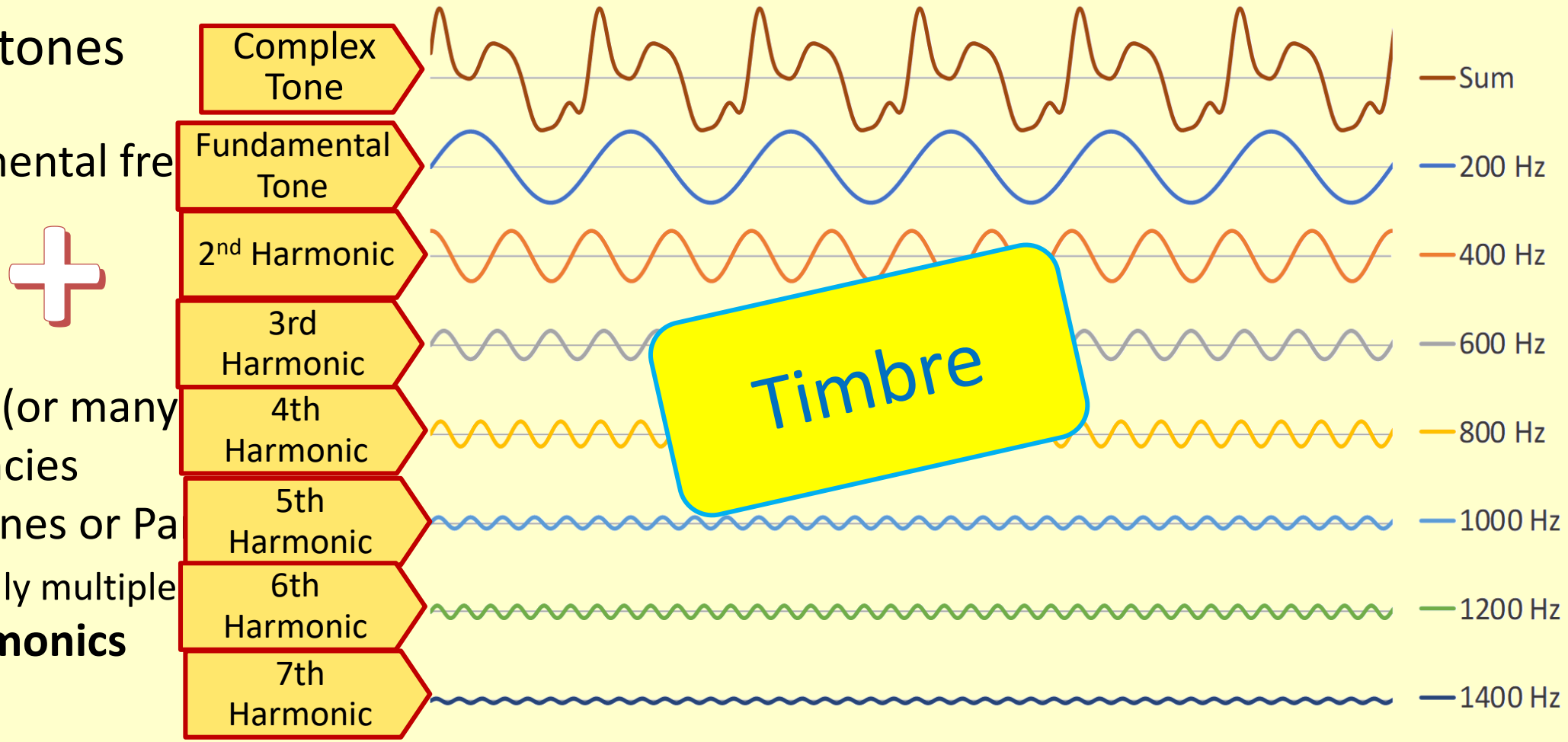
- Complex tones
  - Fundamental frequency f_0
  - Several (or many) higher frequencies (Overtones or Partials)
    - Usually multiples of f_0 called **Harmonics**





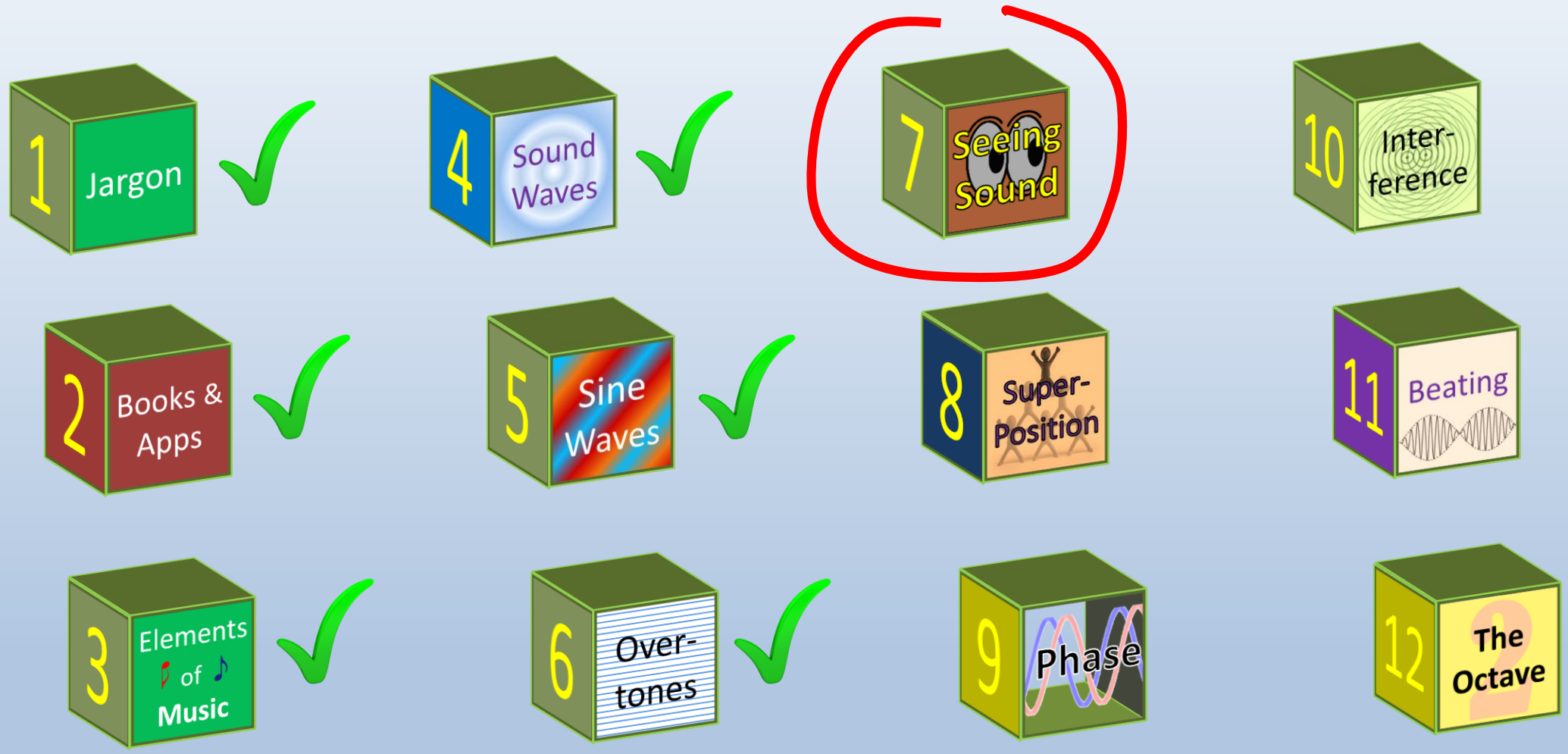
Real Musical Notes are *not* Pure Sine Waves

- Complex tones
  - Fundamental fre
  - Several (or many frequencies (Overtones or Pa
    - Usually multiple **Harmonics**



Musical Instruments and Nature Rarely Make Sine Waves

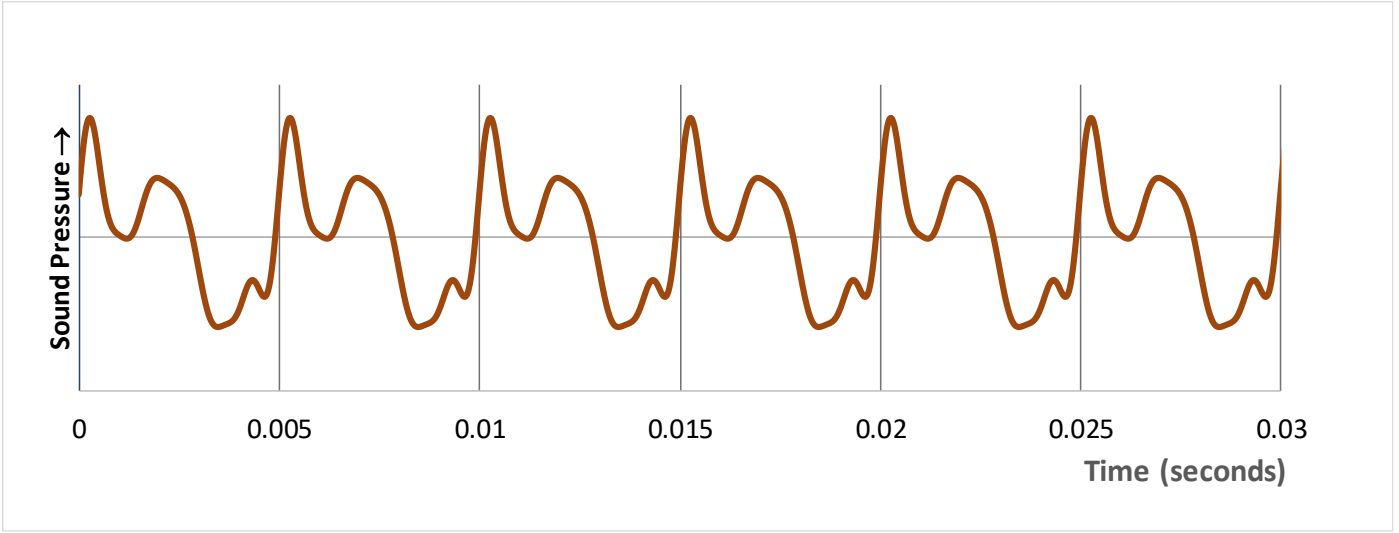
Building Blocks



Visualization of Sound

Two main approaches:

- Waveform Display

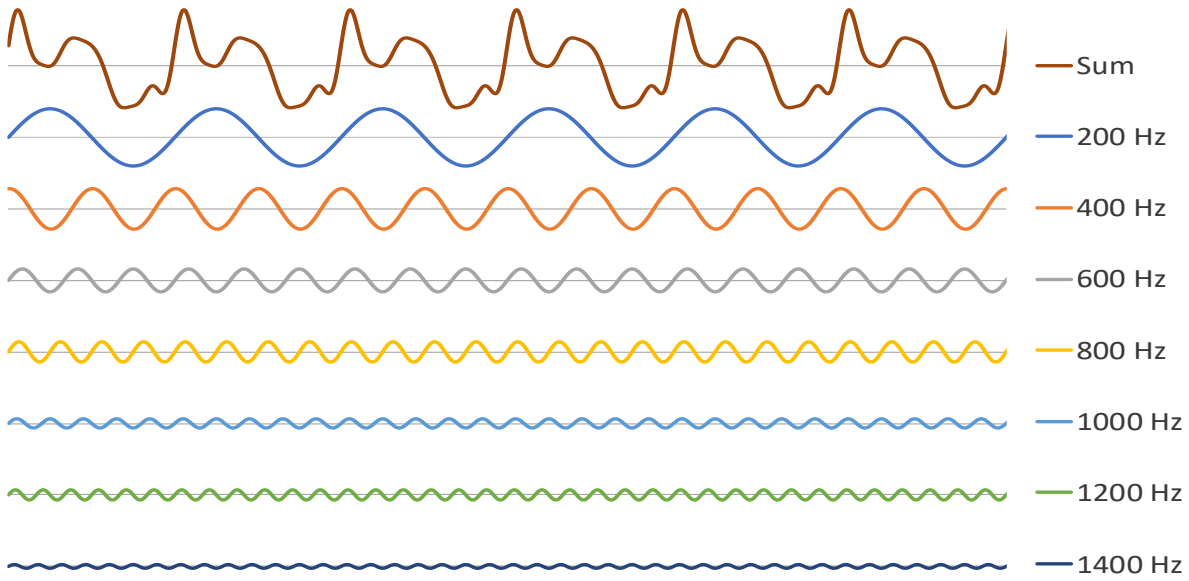


- Spectrum Display

Visualization of Sound: Spectrum

- Remember how our complex waveform was built of sinusoidal harmonics?
- We could just list the constituent Partials:

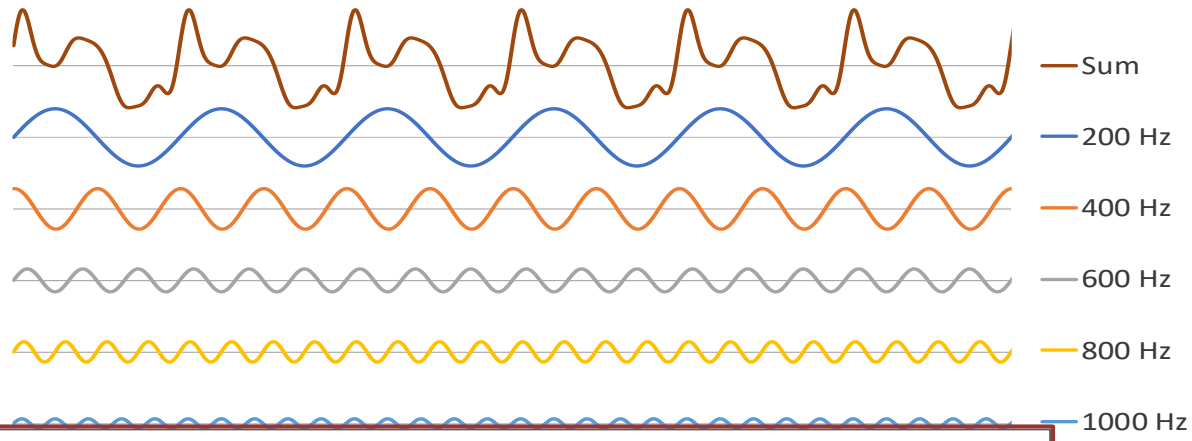
Partial #	Frequency (Hz)	Amplitude
1	200	100%
2	400	71%
3	600	40%
4	800	35%
5	1000	16%
6	1200	18%
7	1400	6%

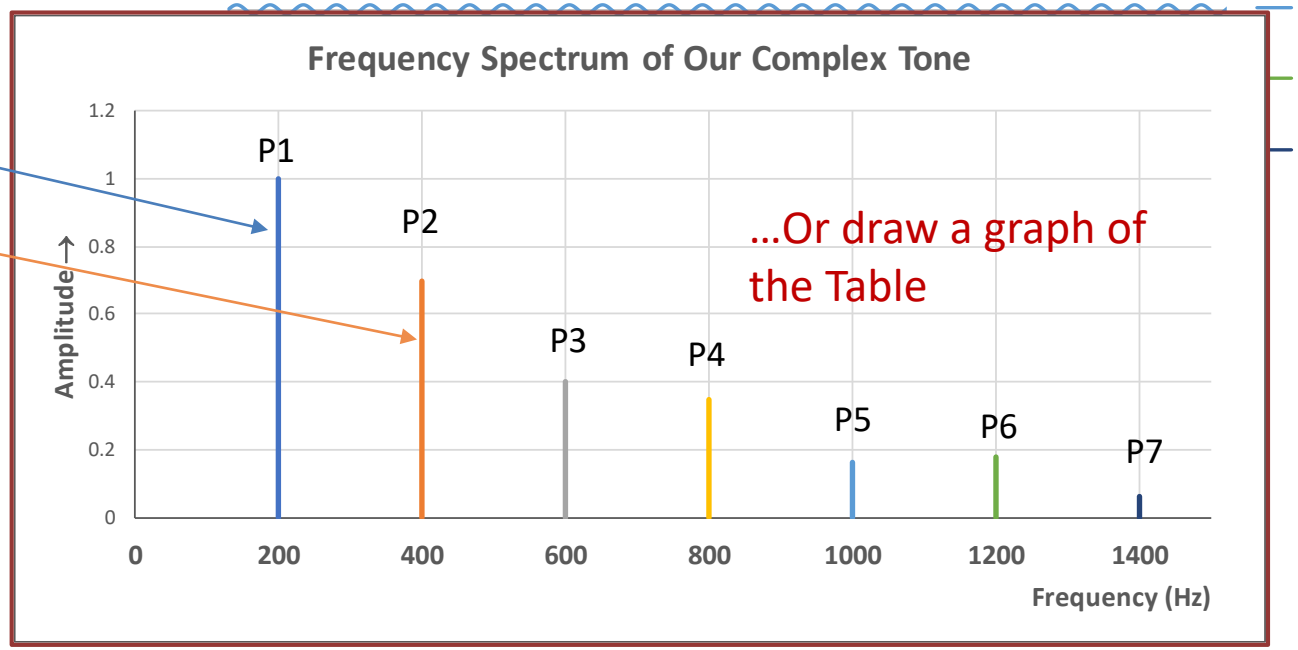


Visualization of Sound: Spectrum

- Remember how our complex waveform was built of sinusoidal harmonics?
- We could just list the constituent Partials:

Partial #	Frequency (Hz)	Amplitude
1	200	100%
2	400	71%
3	600	40%
4	800	35%
5	1000	16%
6	1200	18%
7	1400	6%

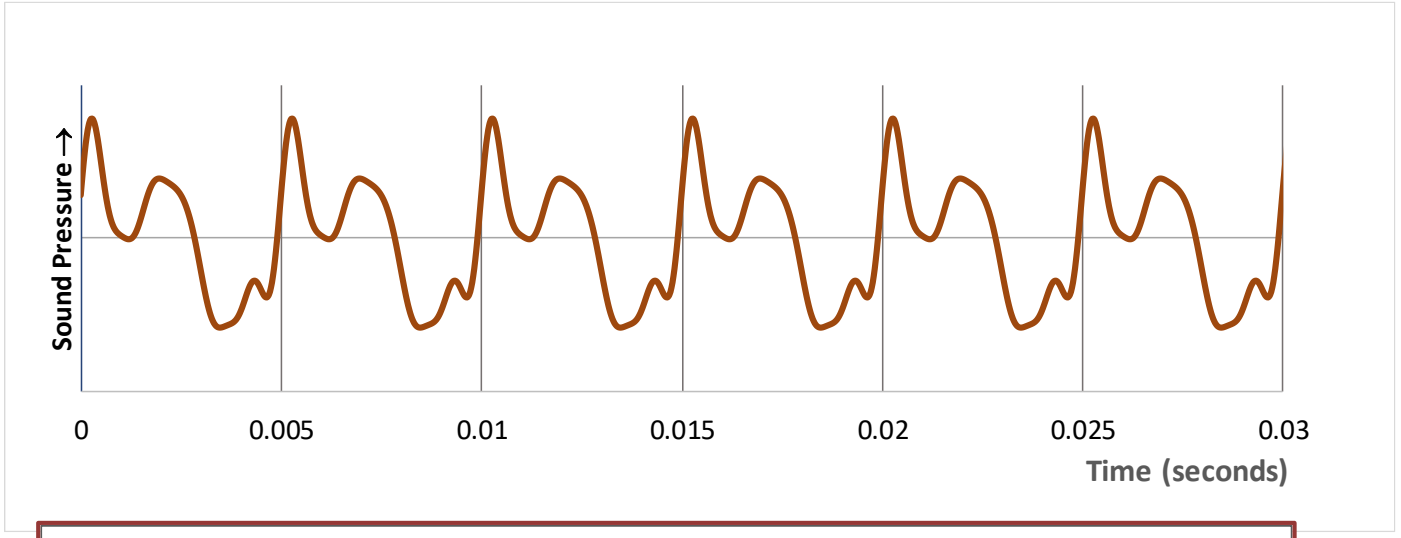




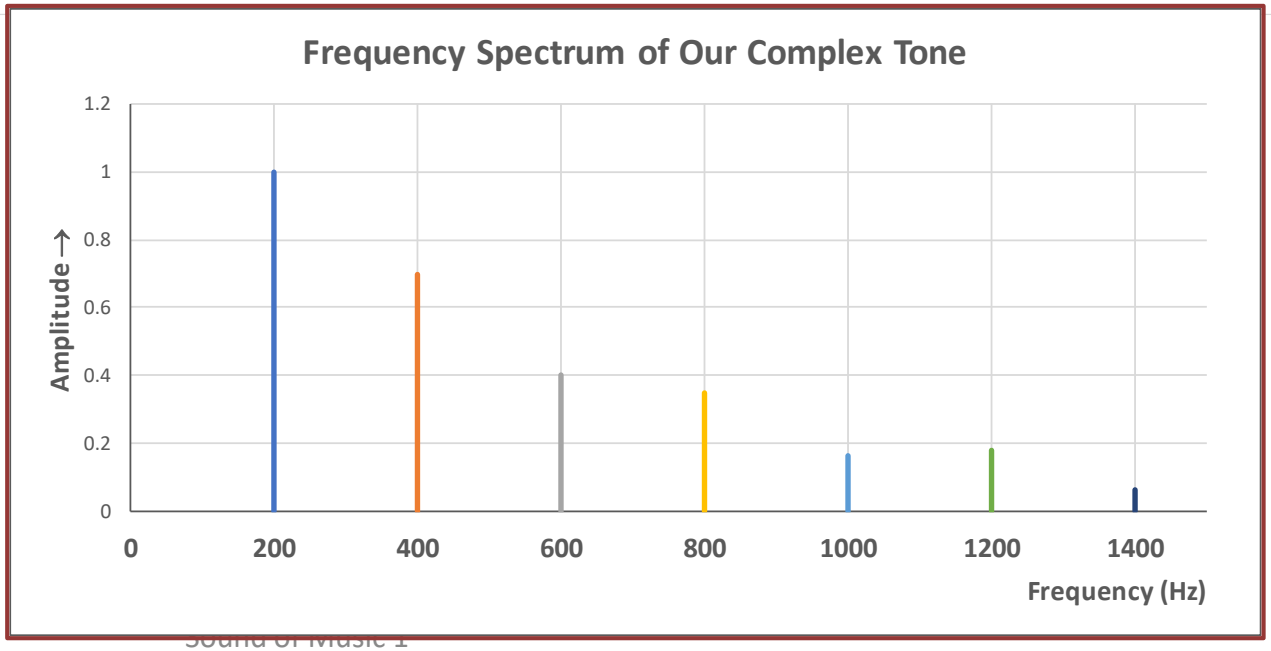
Visualization of Sound

Two main approaches:

- Waveform Display



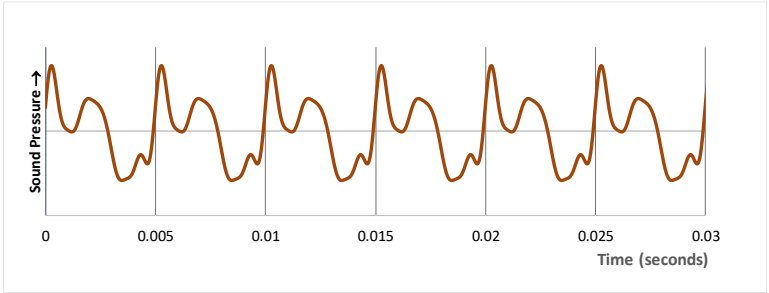
- Spectrum Display



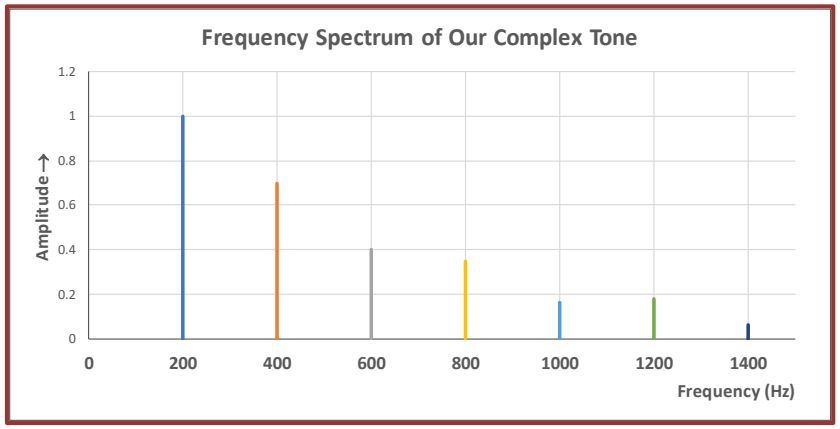
Visualization of Sound

Two main approaches:

- Waveform Display

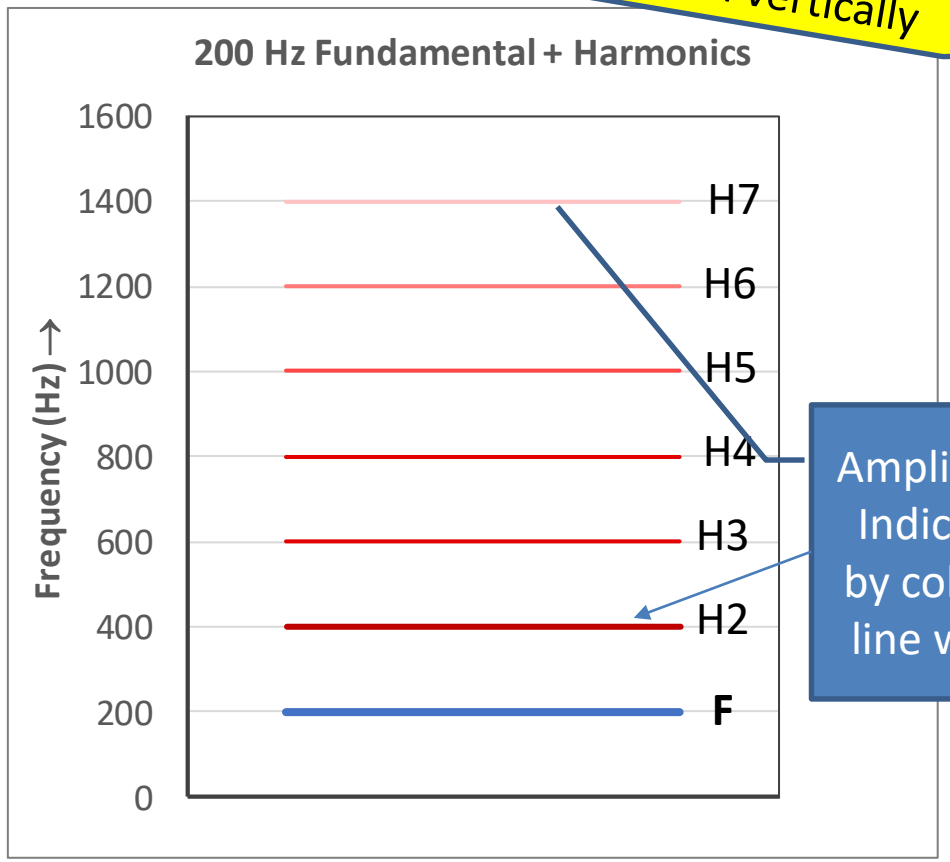


- Spectrum Display



Alternate Spectrum Presentation

So, sometimes Frequencies are shown vertically

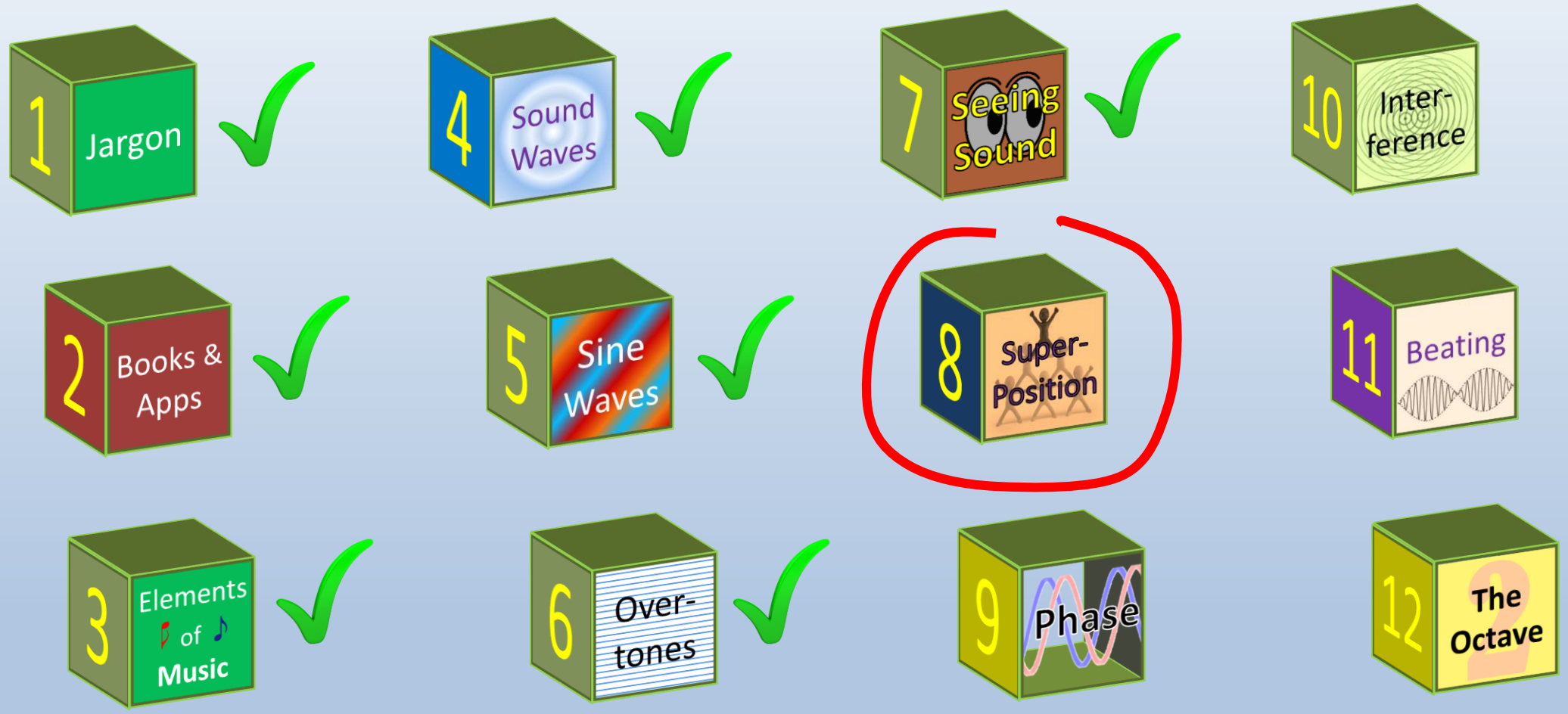


Amplitudes Indicated by color or line width

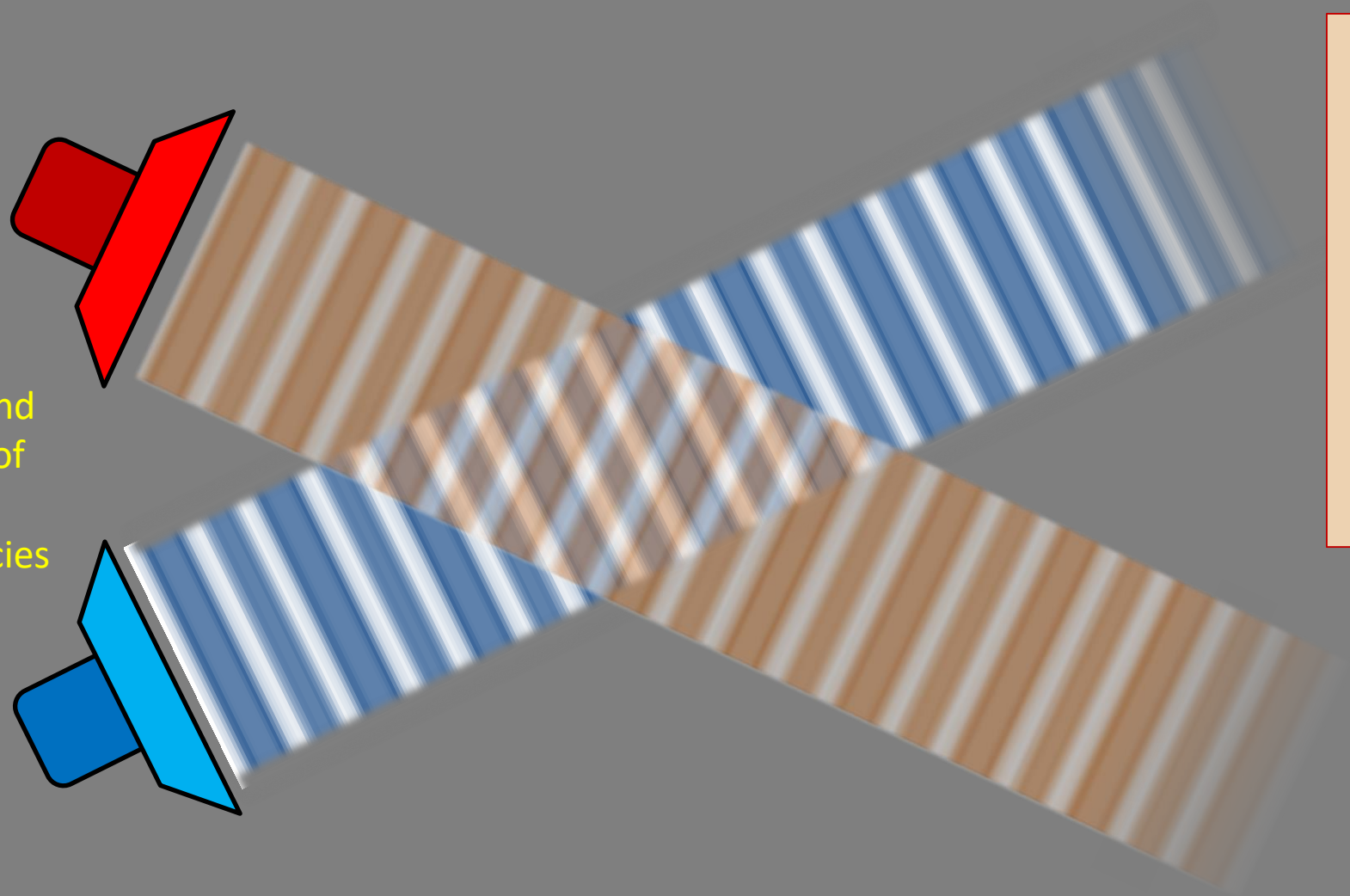
Visualization of Sound

Demo failed due to software problem

Building Blocks



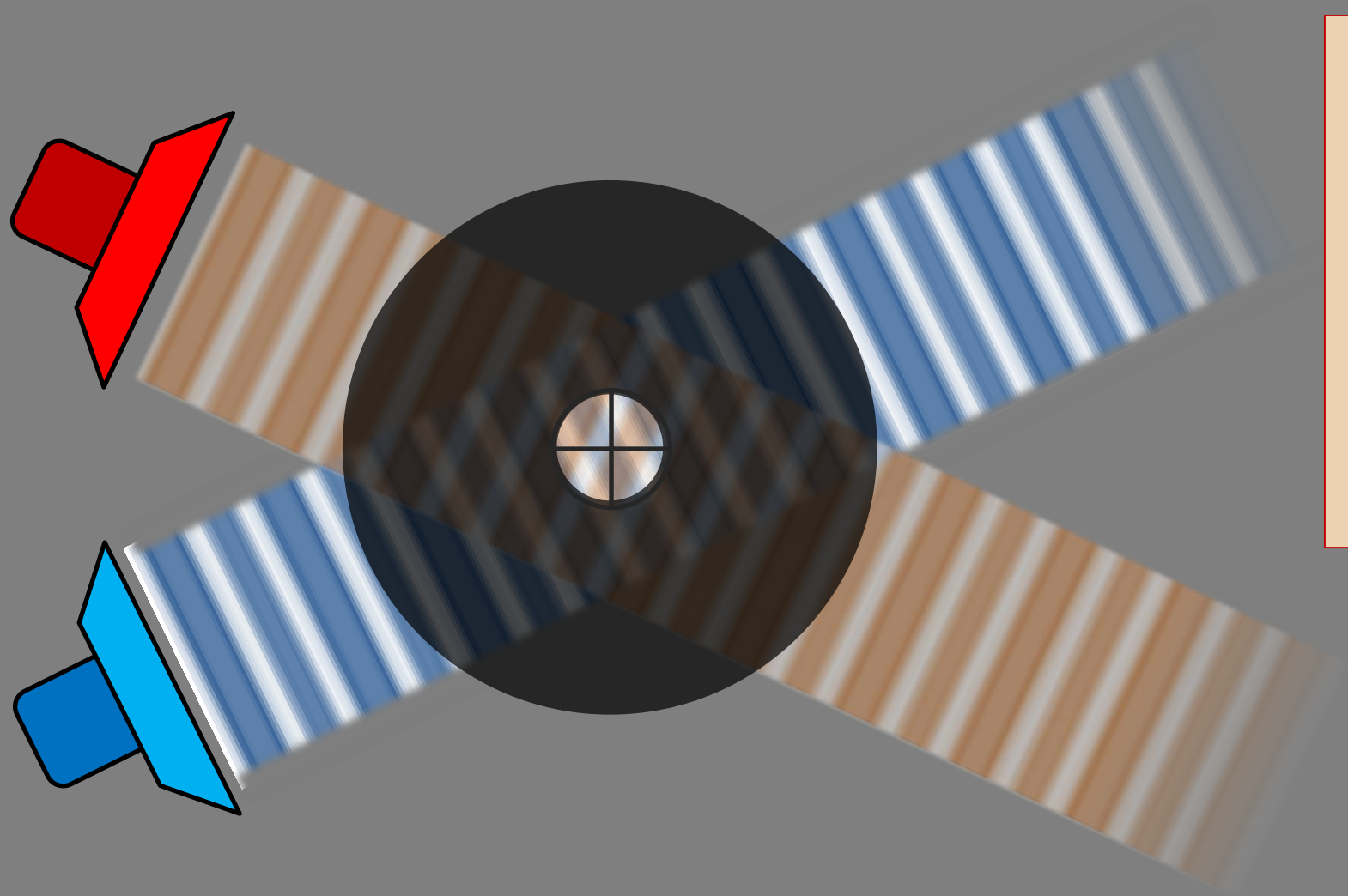
Superposition of Sound Waves



Two sound sources of different frequencies

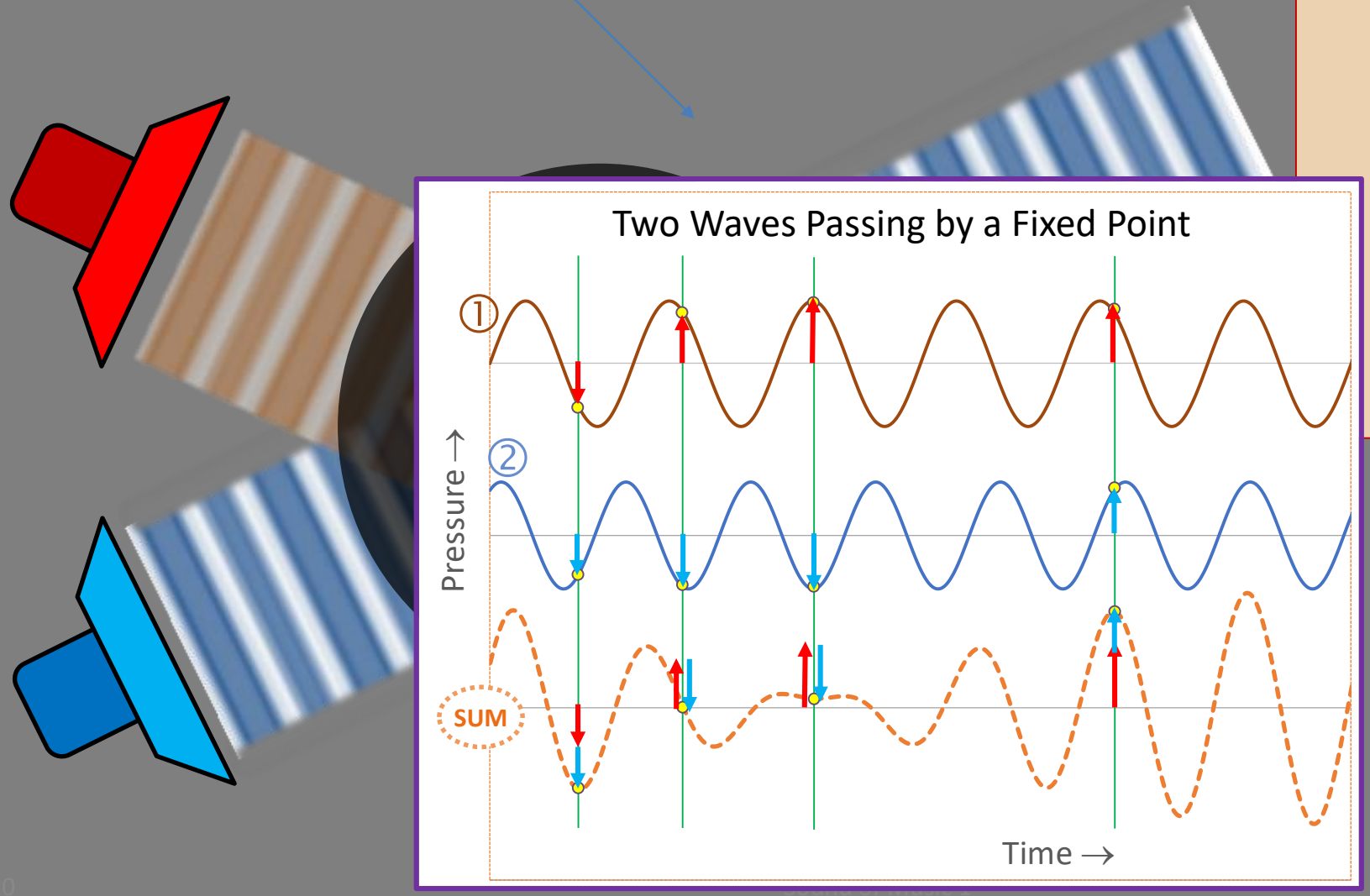
- Waves pass through one another without disruption
- Where they overlap, **Superposition** applies:
  --Pressures add up

Superposition of Sound Waves



- Waves pass through one another without disruption
- Where they overlap, **Superposition** applies:
  --Pressures add up

Superposition of Sound Waves

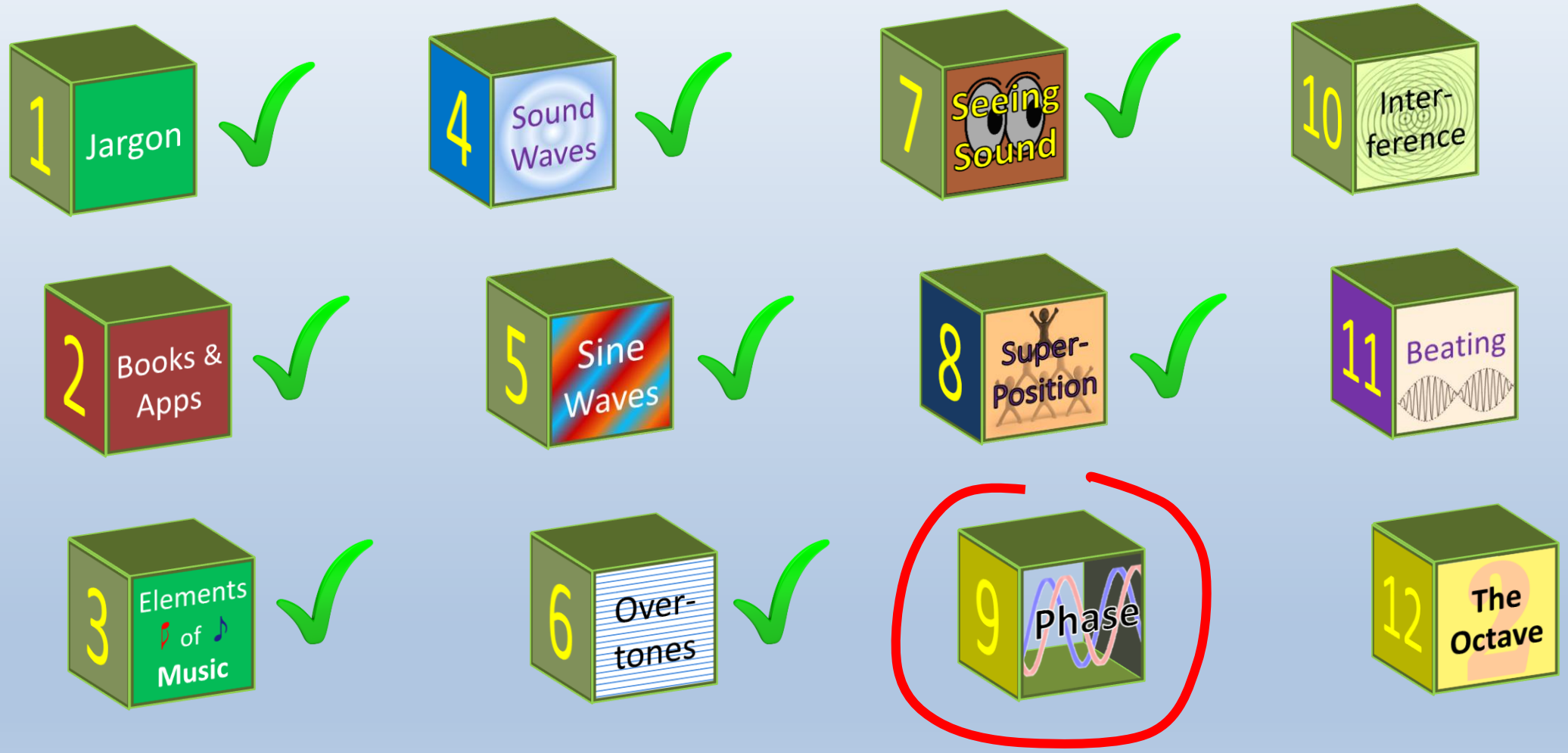


- Waves pass through one another without disruption

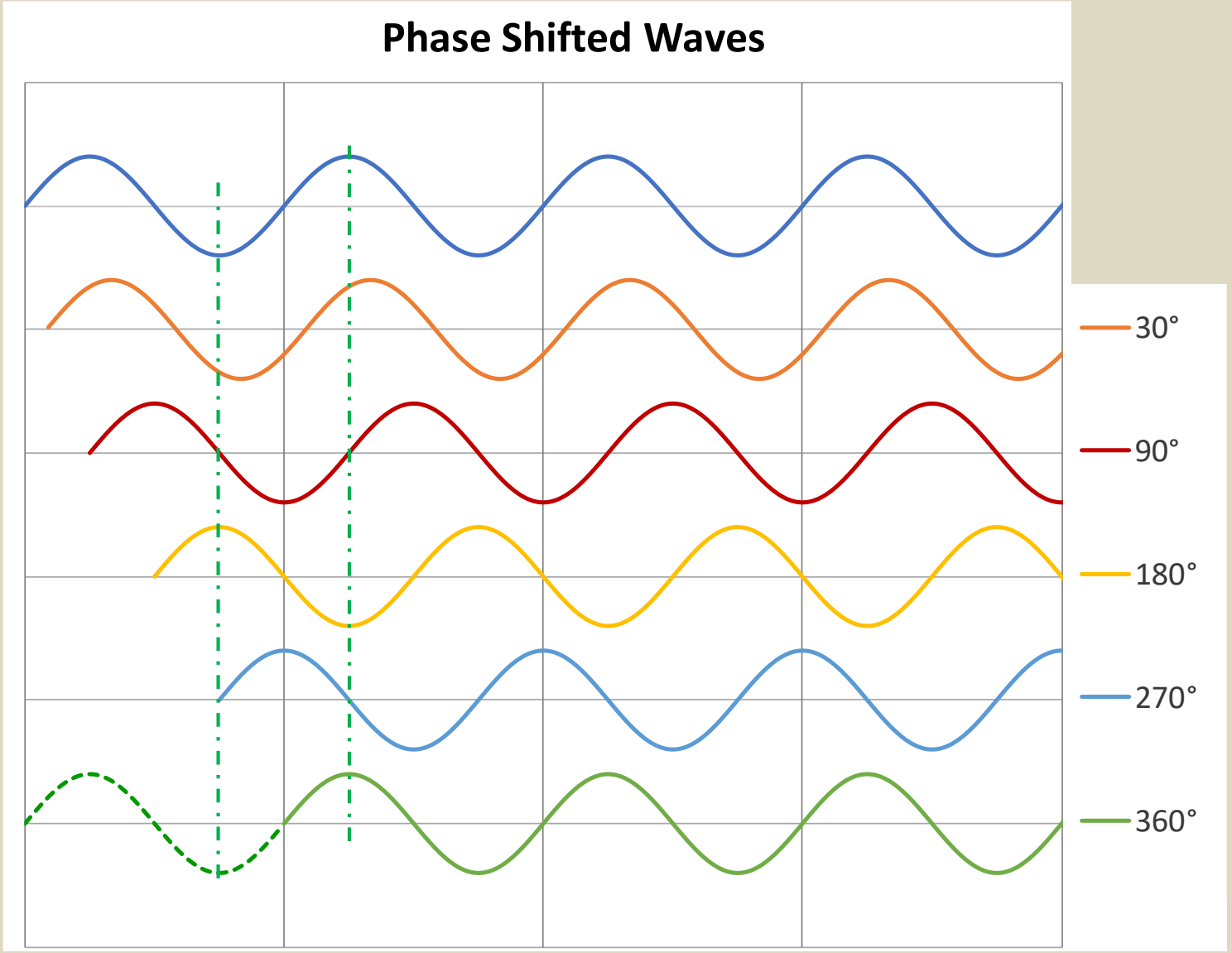
Where they overlap, **Superposition** applies:
--Pressures add up

Sometimes they add up to a bigger amplitude, but sometimes they cancel each other

Building Blocks



Phase: Delayed Waves

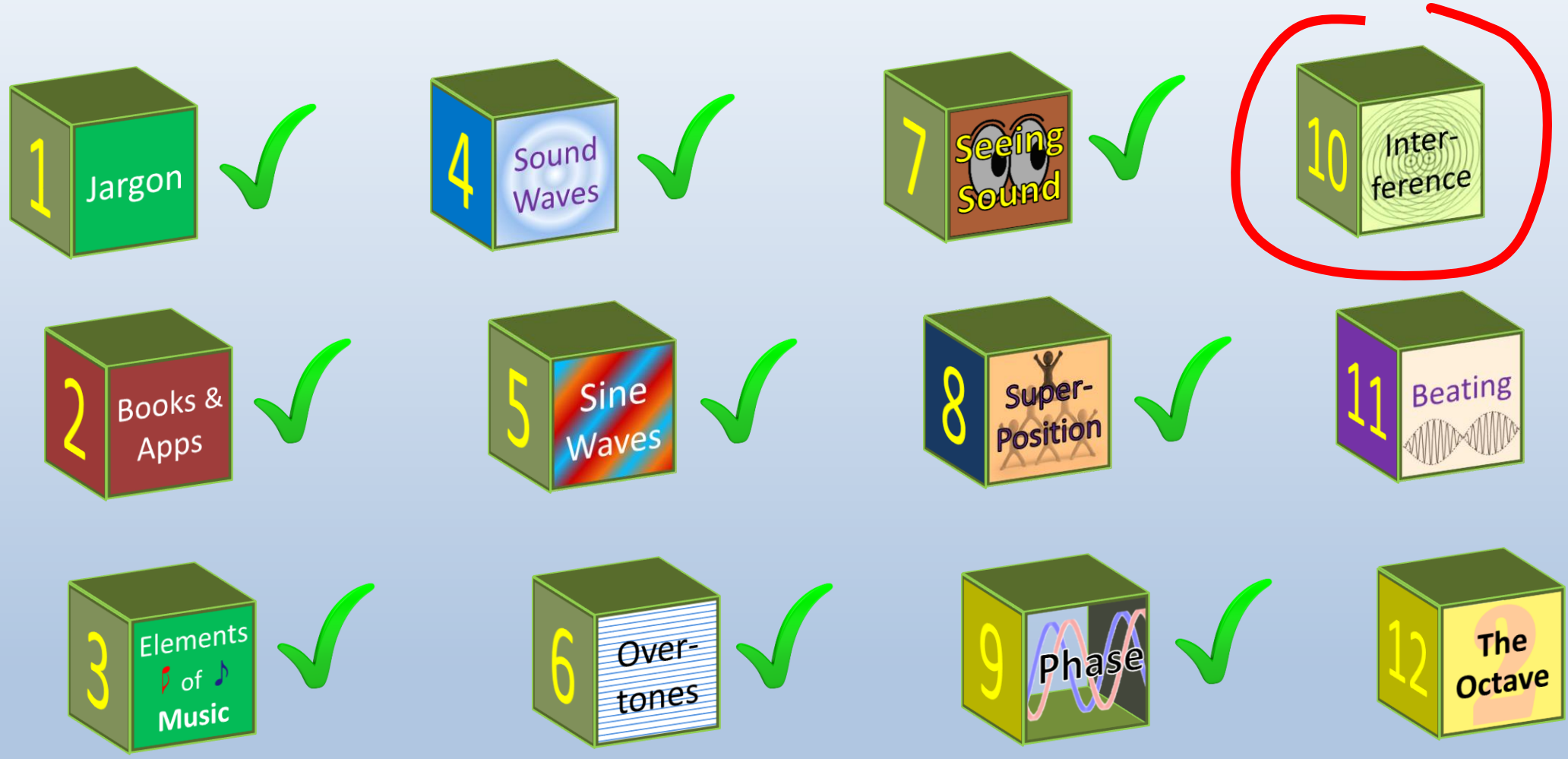


- Phase refers to time shifts between waves of the *same* or *similar* frequency
- Measured in Degrees
  360° = Full Cycle

Green wave is shifted by 360°, or a full wave cycle.

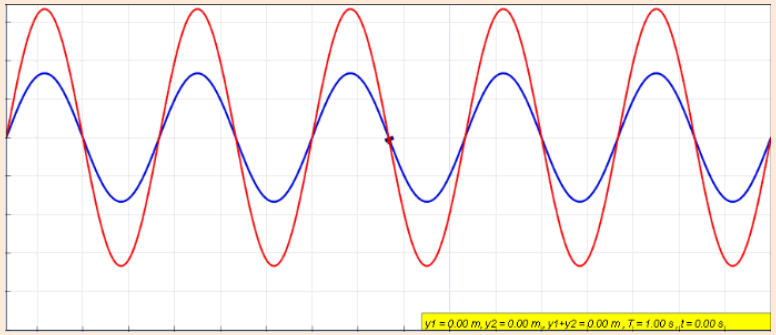
Therefore looks just like the original Blue wave.

Building Blocks

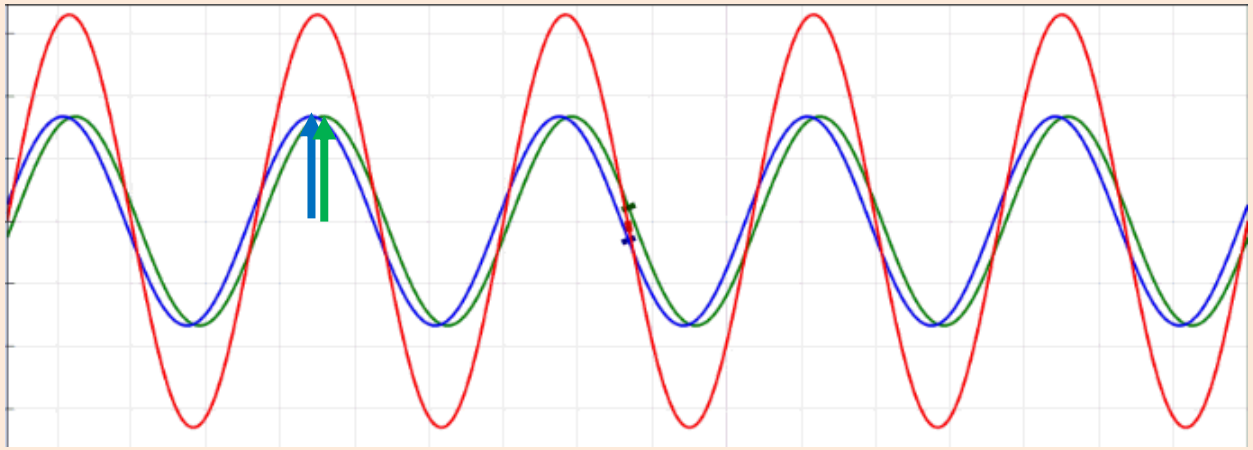


Interfering Waves

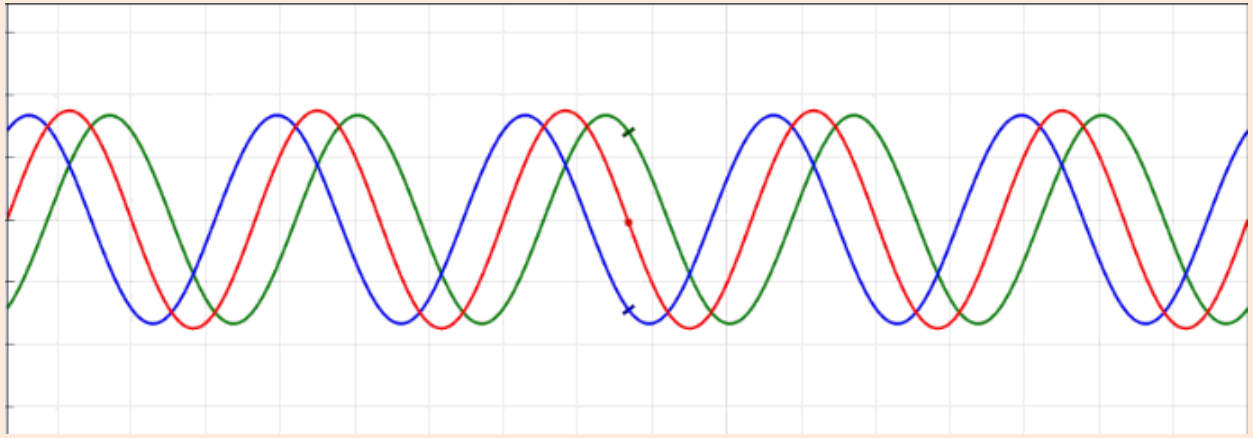
Blue wave and
Phase-Shifted Green wave
Add up to Red wave



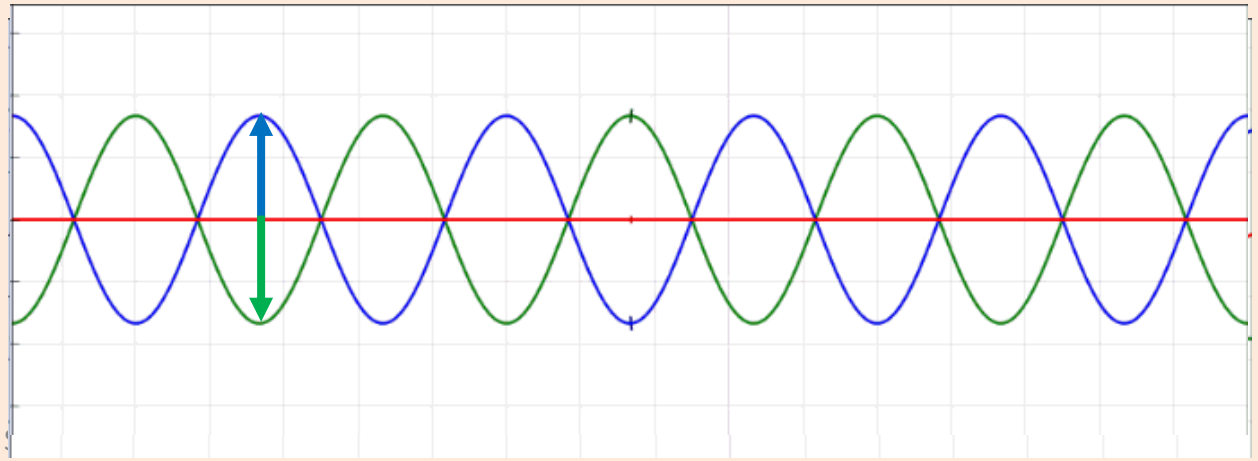
10°



90°

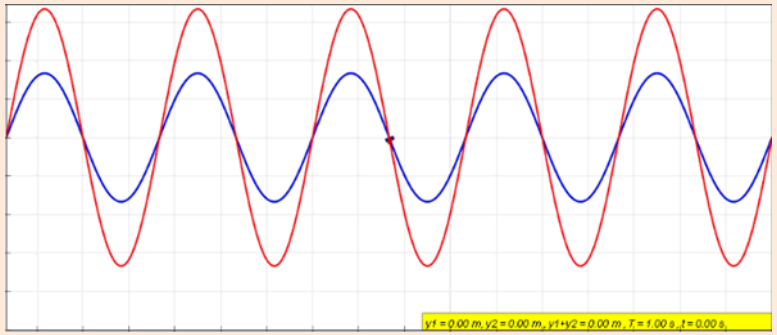


180°

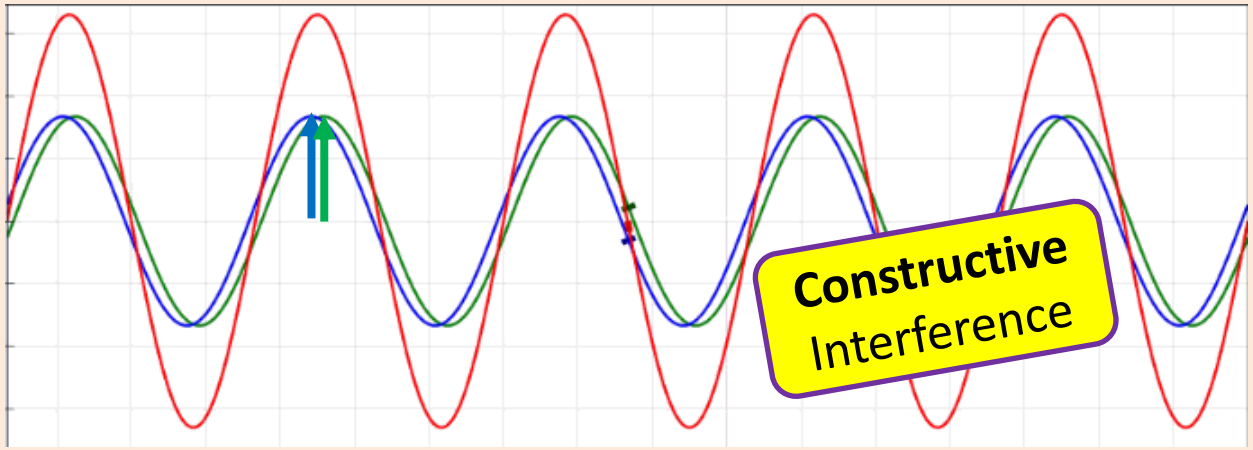


Interfering Waves

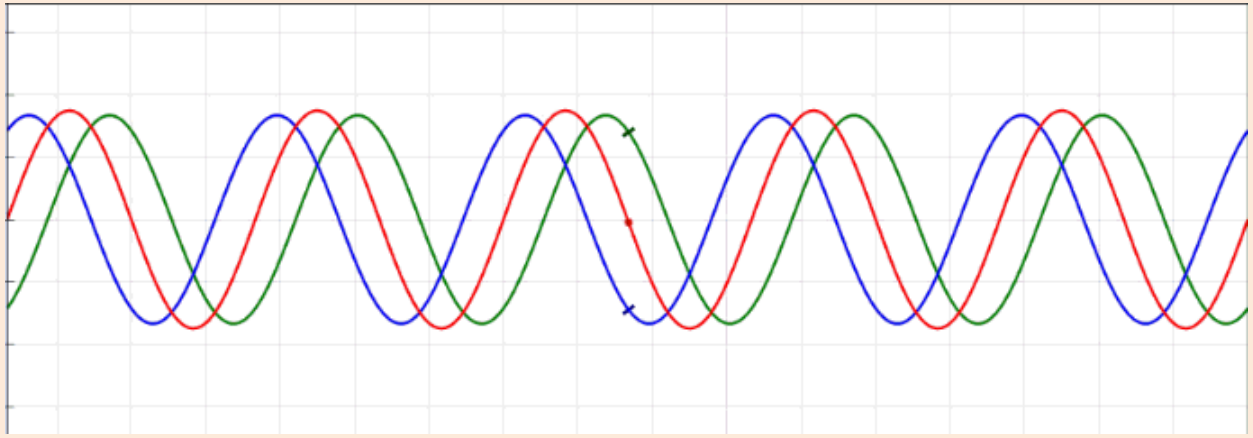
Blue wave and
Phase-Shifted Green wave
Add up to Red wave



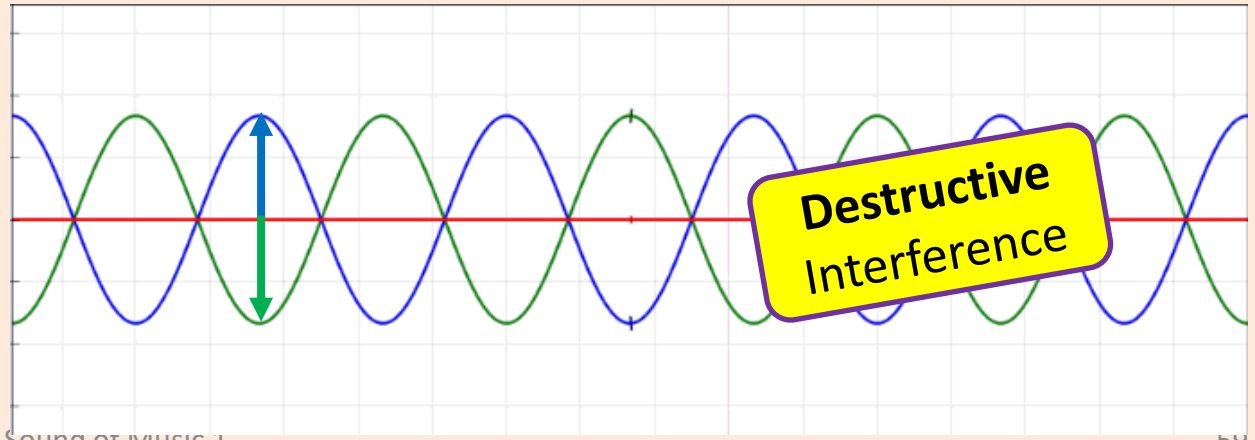
10°



90°

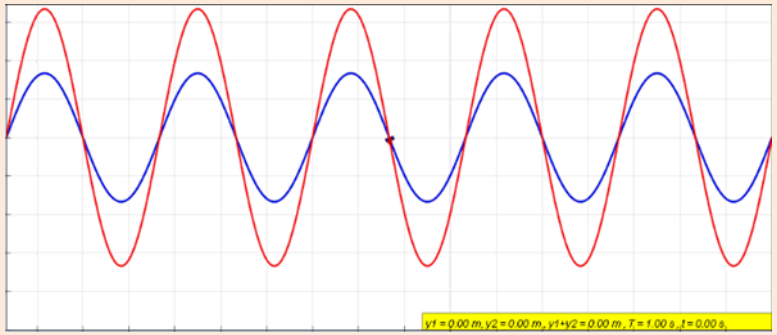


180°



Interfering Waves

Blue wave and
Phase-Shifted Green wave
Add up to Red wave



10°

Demo

Constructive Interference

90°

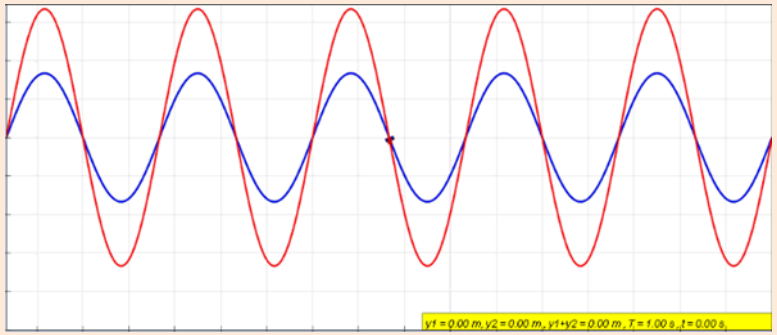
2 Speakers emitting
329 Hz Sine Waves

180°

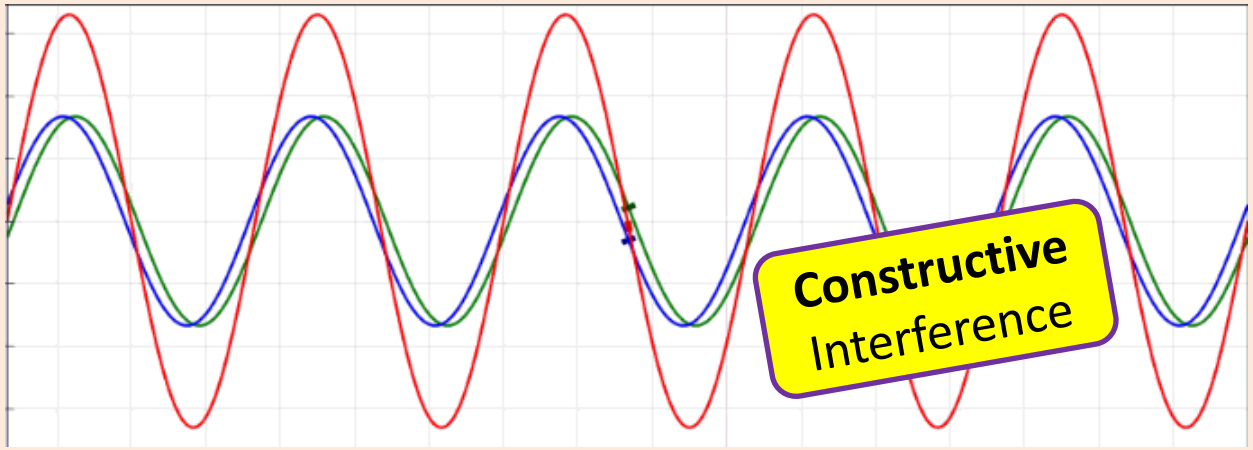
Destructive Interference

Interfering Waves

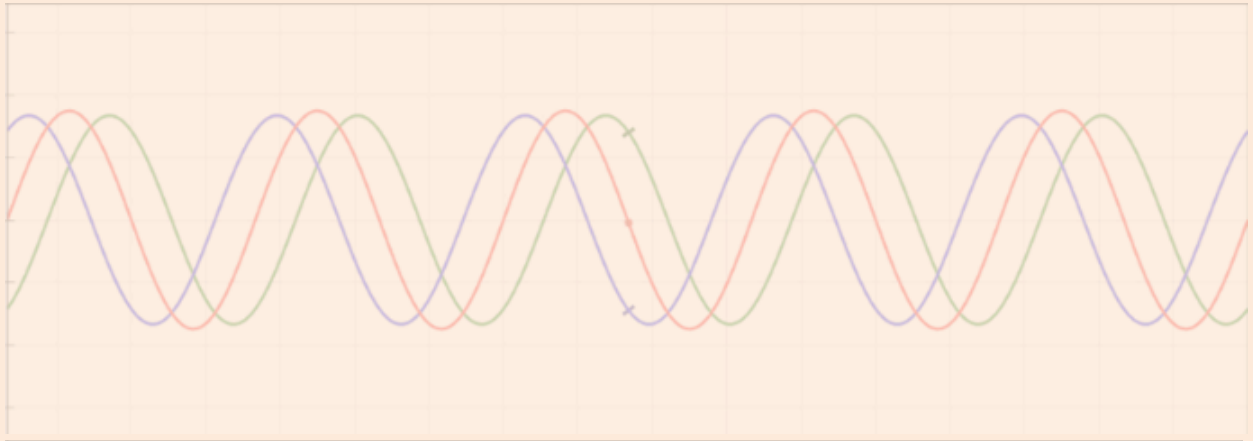
Blue wave and
Phase-Shifted Green wave
Add up to Red wave



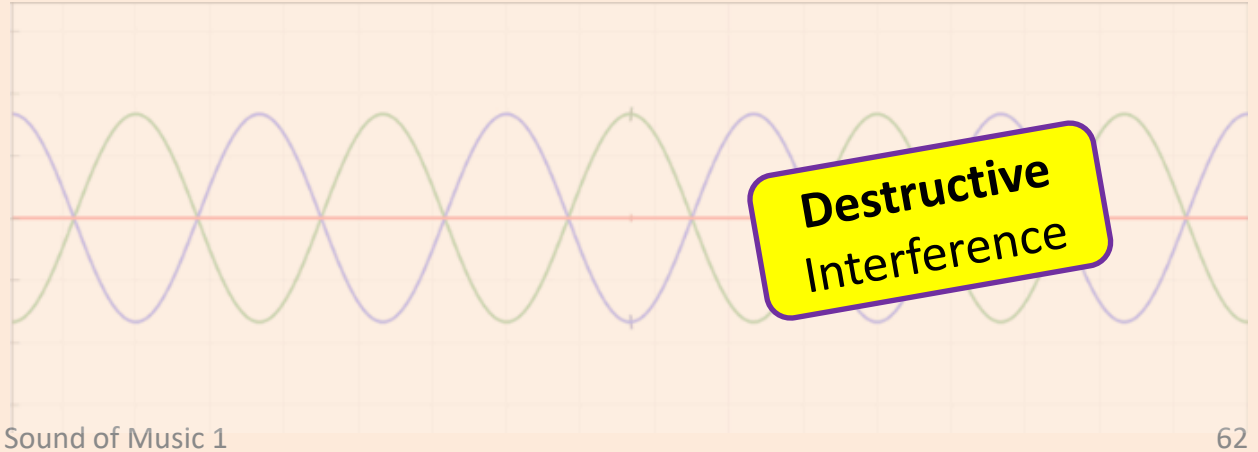
10°



90°

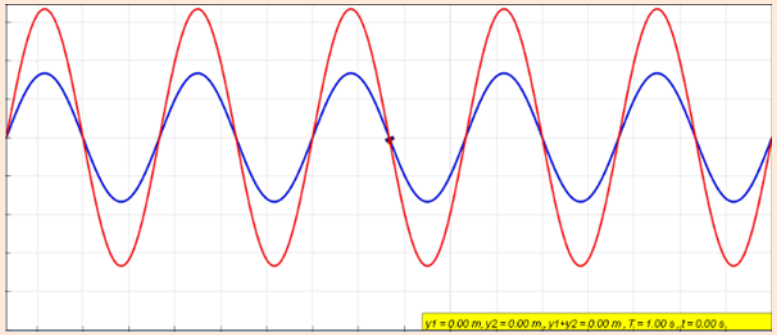


180°

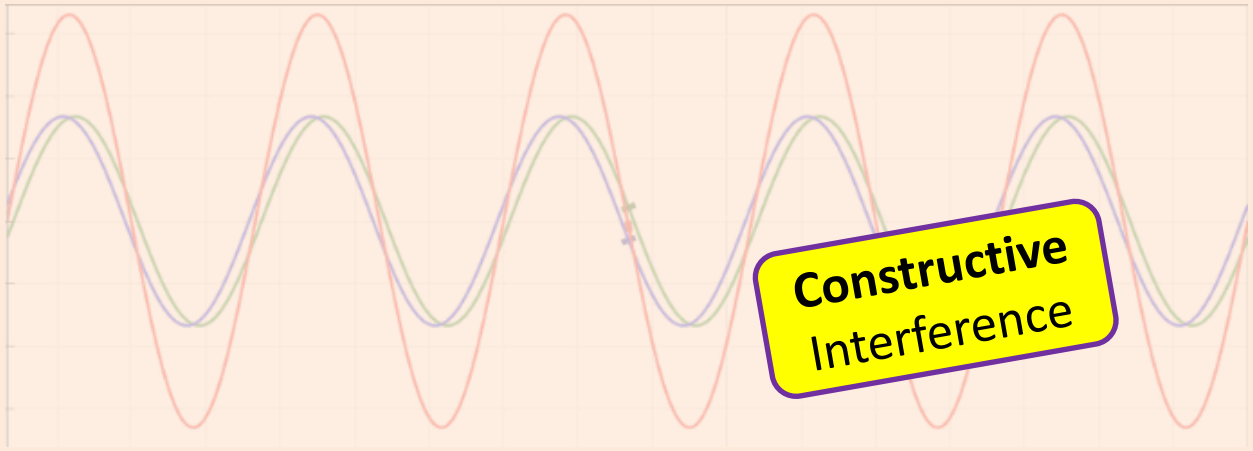


Interfering Waves

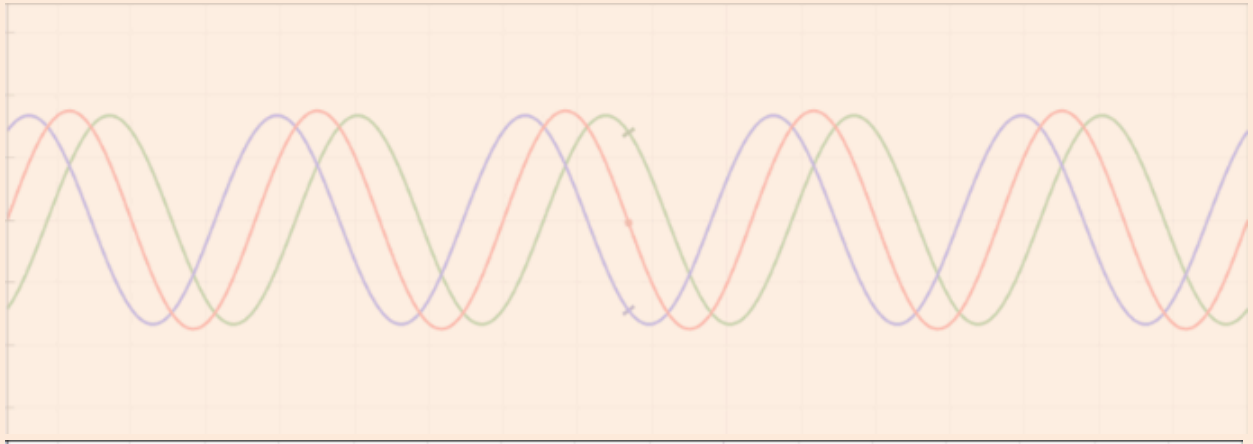
Blue wave and
Phase-Shifted Green wave
Add up to Red wave



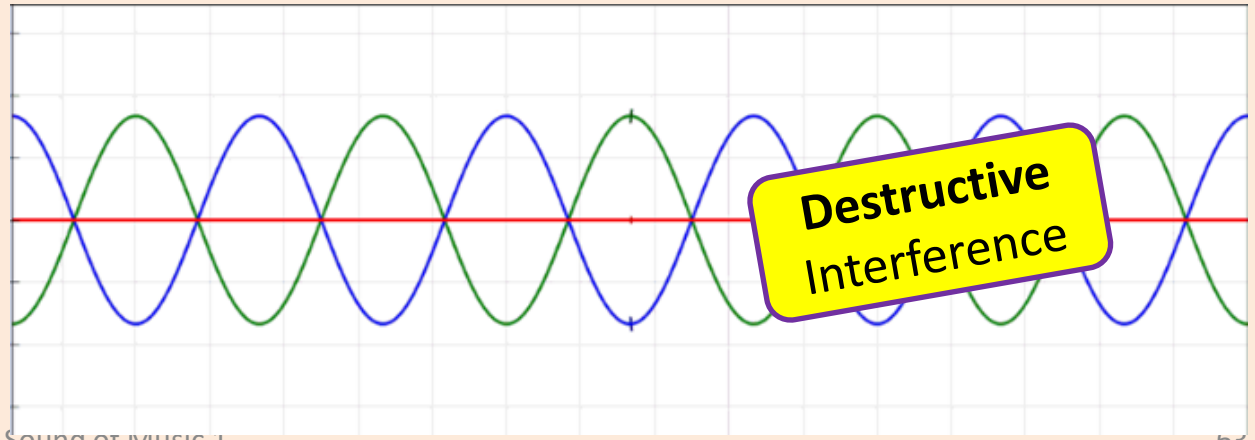
10°



90°

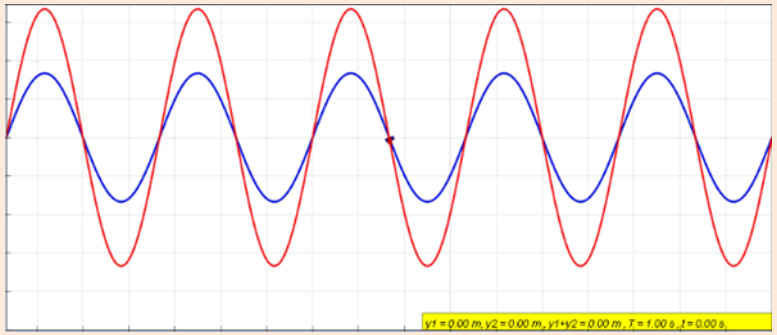


180°

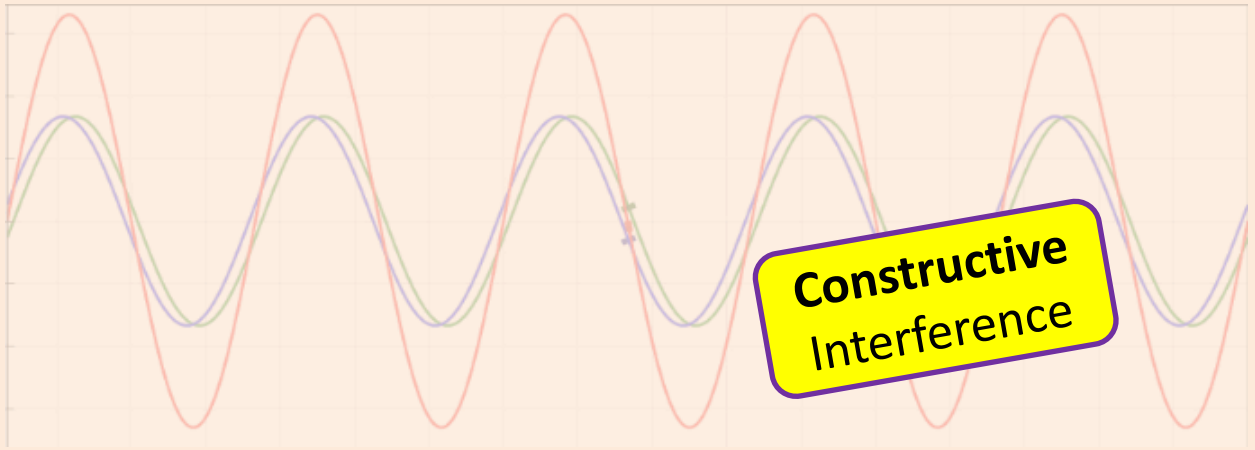


Interfering Waves

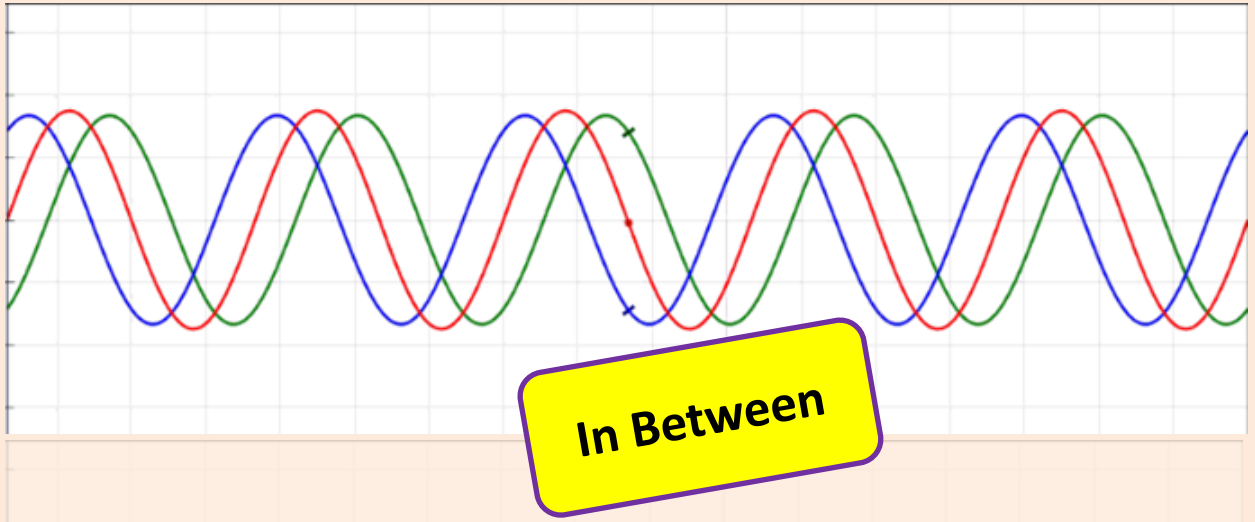
Blue wave and
Phase-Shifted Green wave
Add up to Red wave



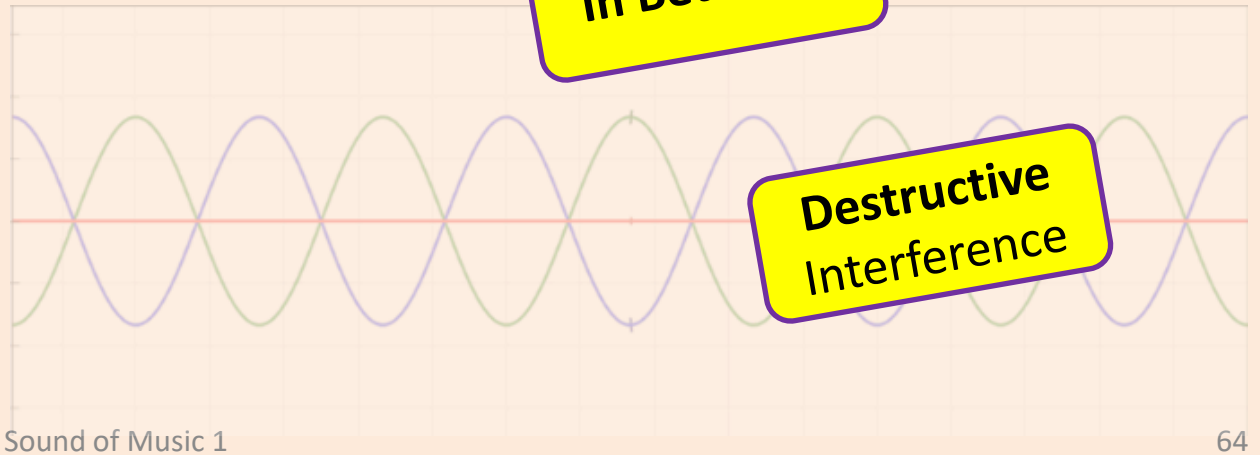
10°



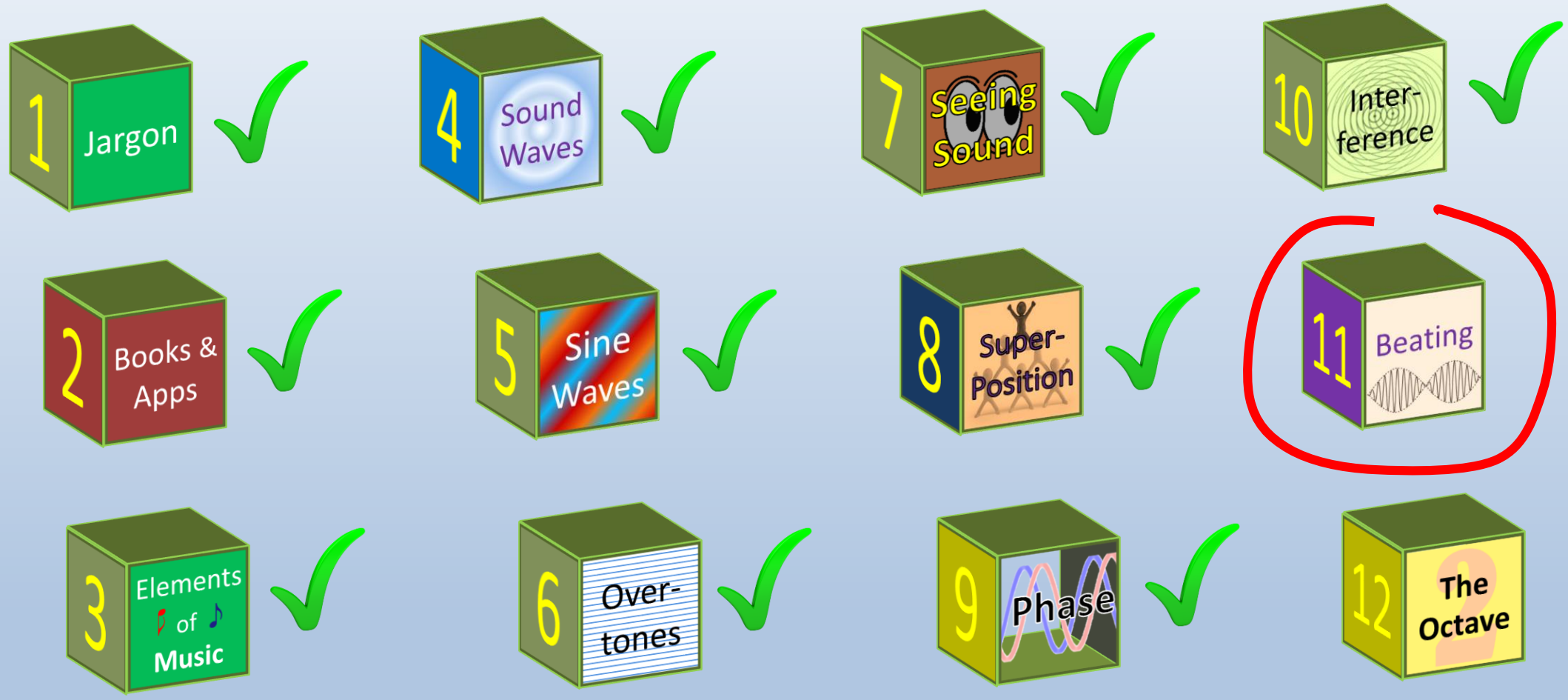
90°



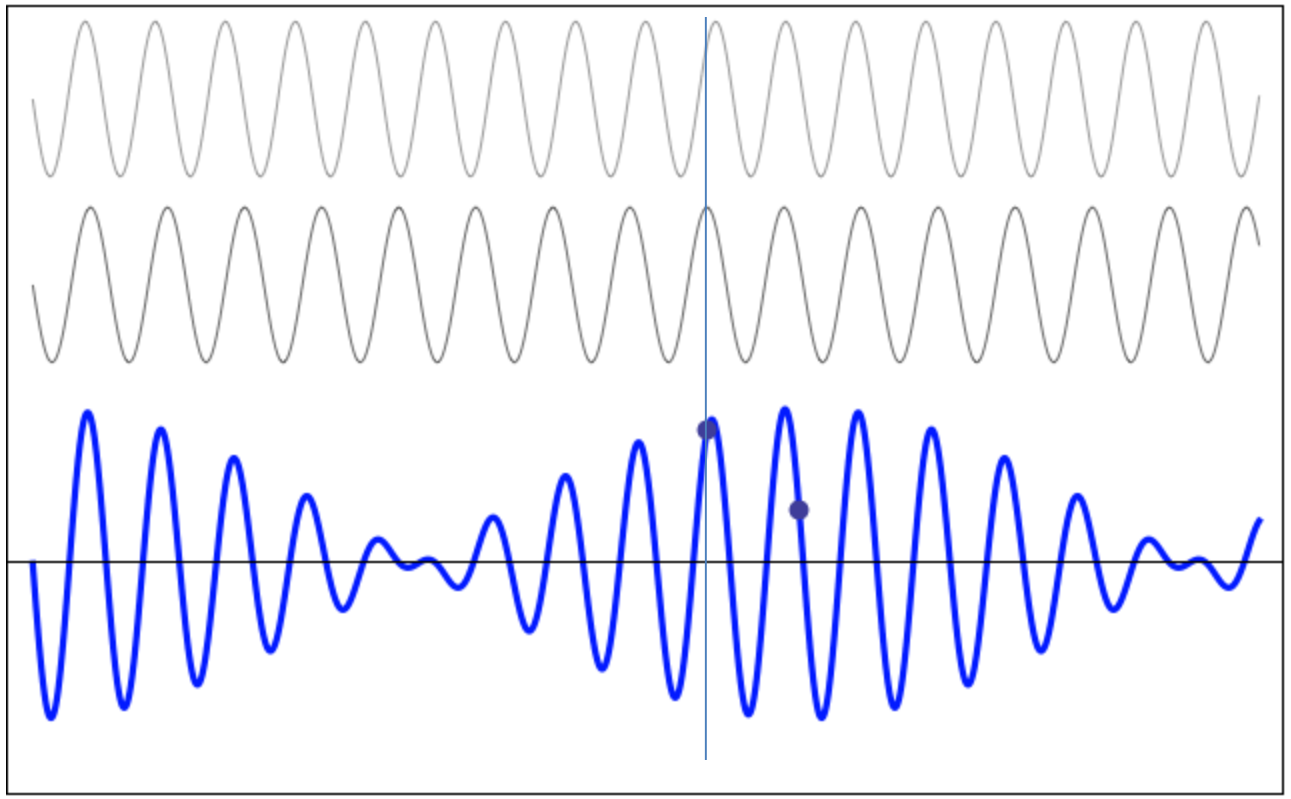
180°



Building Blocks



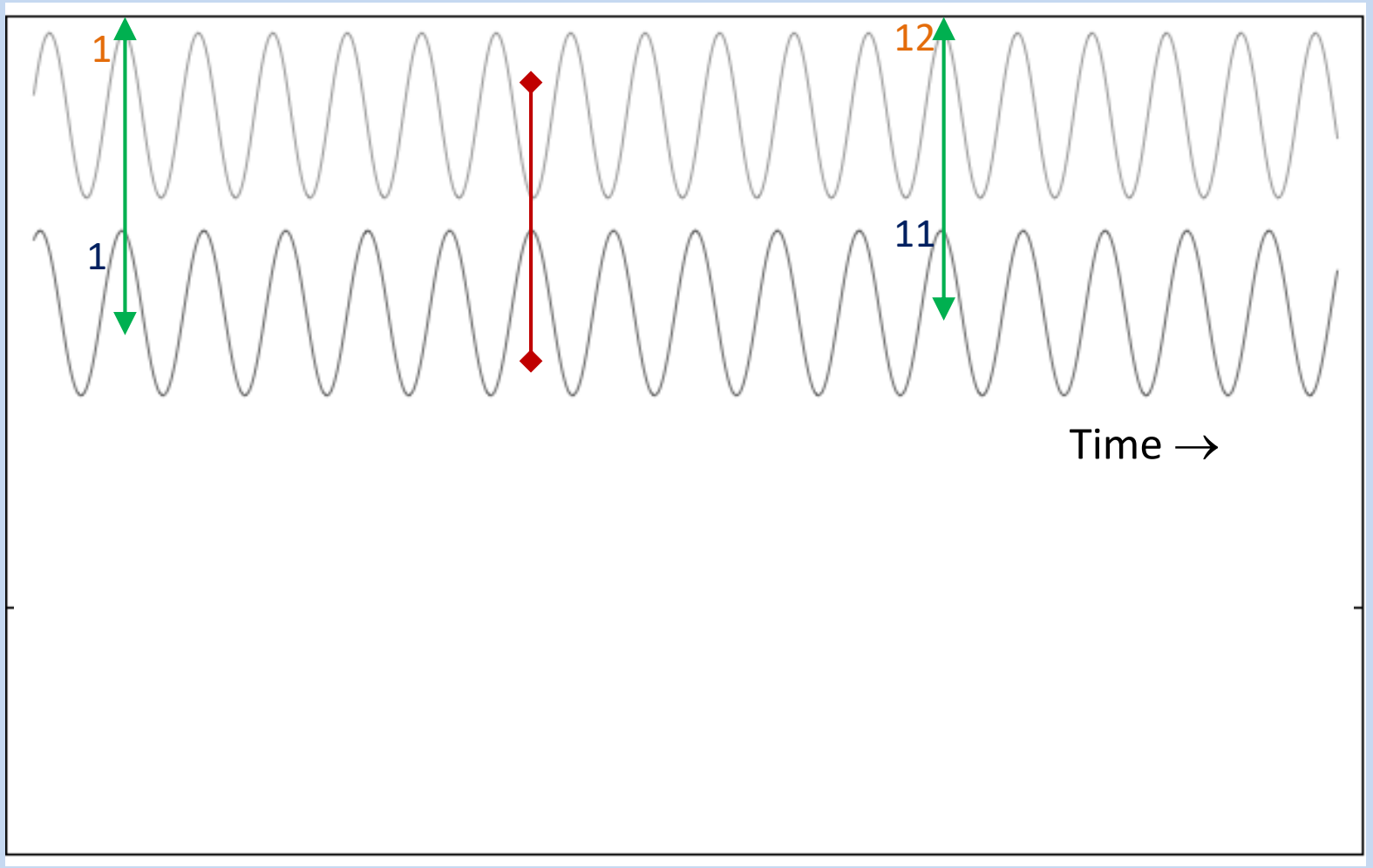
Beating: *Interference in Action*



Beating: *Interference in Action*

Higher Frequency

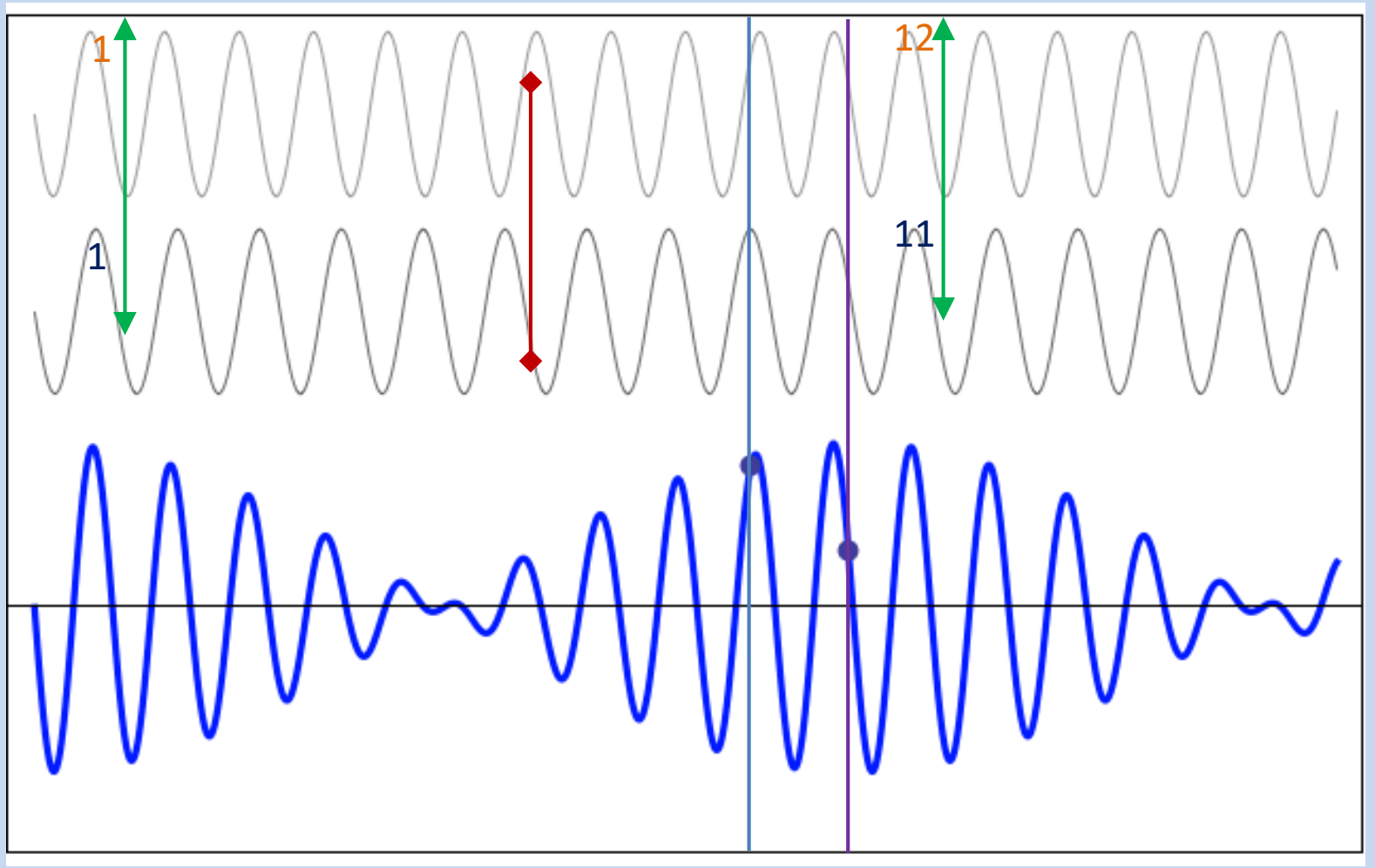
Lower Frequency



Beating: *Interference in Action*

Higher Frequency

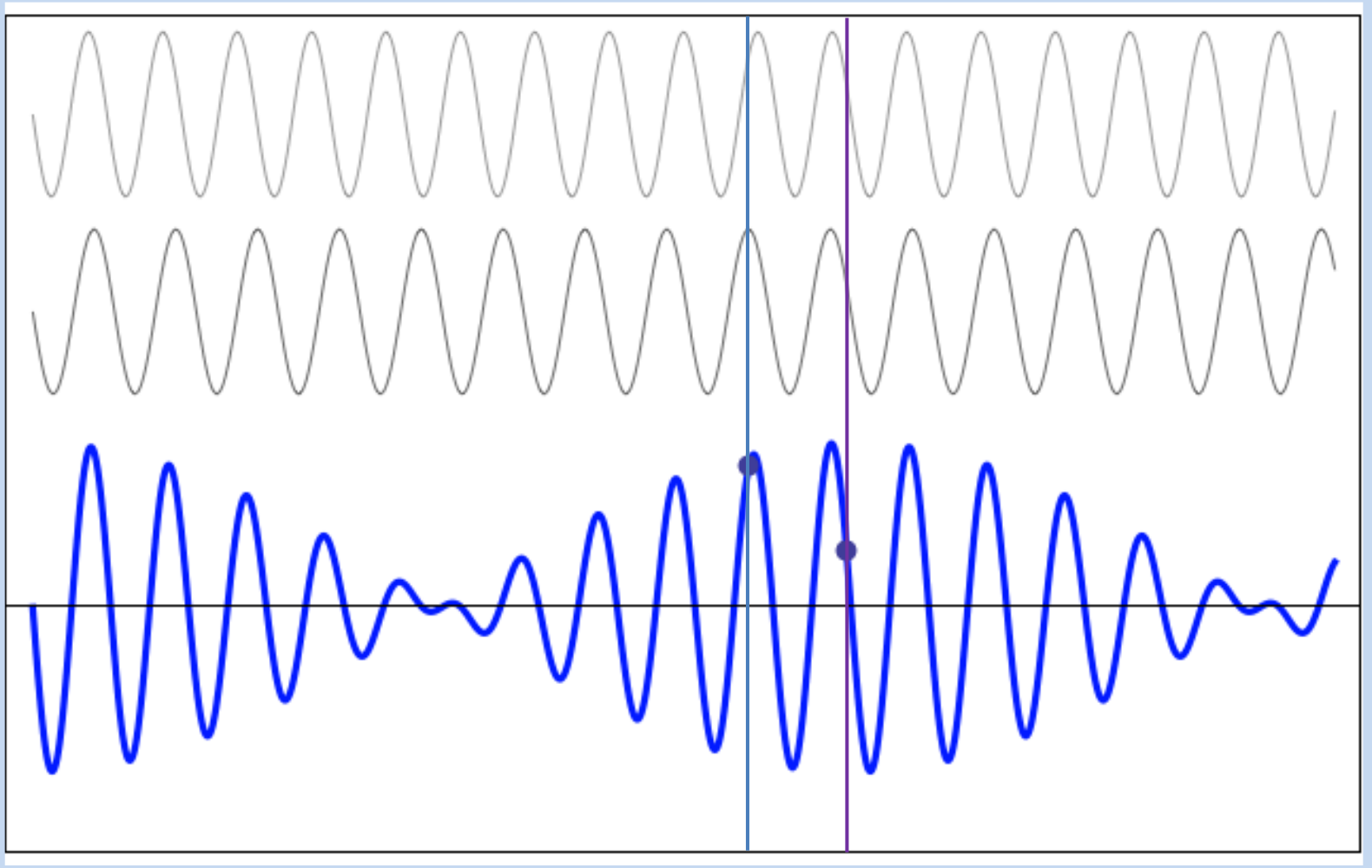
Lower Frequency



Beating: *Interference in Action*

Higher Frequency

Lower Frequency



Demo

329 Hz + 330 Hz gives 1 Hz Beat, etc.

Beating: *Interference in Action*

Another Example:

3 Simultaneous Tones:

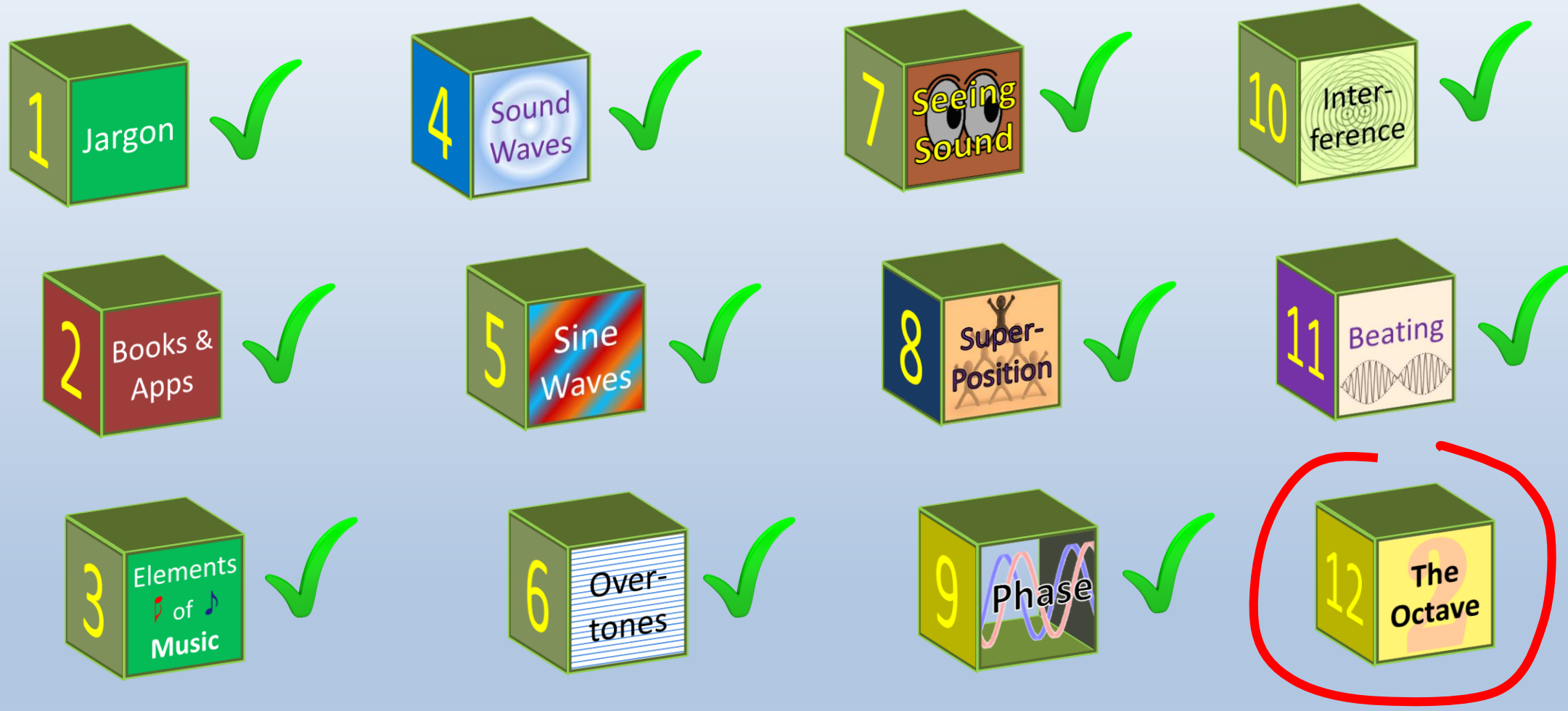
440 Hz

441 Hz

443 Hz

Hear complex beat pattern
(1Hz, 2 Hz and 3 Hz)

Building Blocks



The Octave: Doubling the Frequency

- Doubling or Halving the Frequency has special significance in all musical traditions.

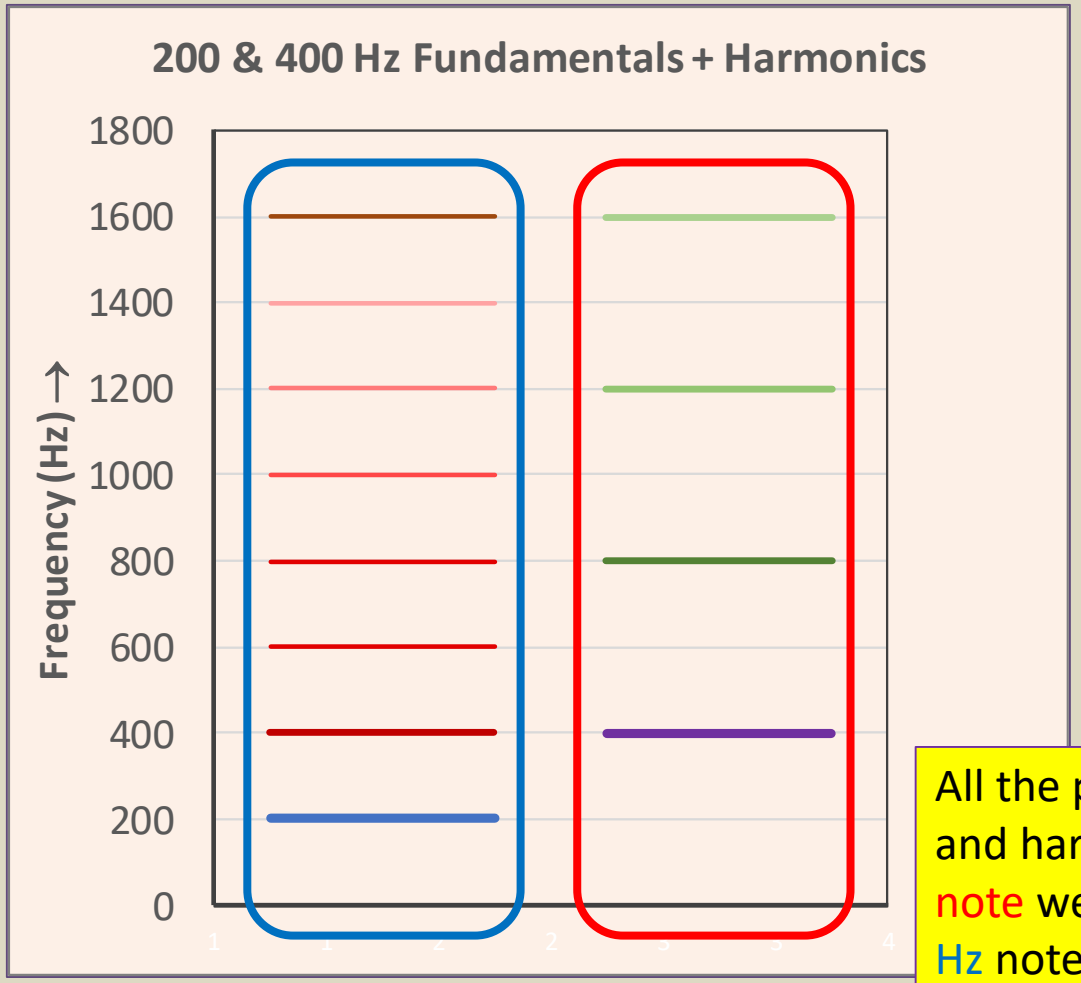
- A musical Note and its Octave (i.e. double f) sound *especially good* together.

  2:1 is the most harmonious ratio

- If a Note with Fundamental Frequency f exists in a musical tradition,

  then so does its Octave $2f$.

The Octave: Doubling the Frequency



These tones have 12 harmonics

	400 Hz	402 Hz	410 Hz	420 Hz
200 Hz	Nice!	Beats!	Harsh!	Harsher!
	200 + 400	200 + 402	200 + 410	200 + 420
		200 + 403		

All the partials (Fundamental and harmonics) of the 400 Hz note were already in the 200 Hz note! So they sound good together.

The Octave: Remembering It

-where

2x

Some

The Octave: Remembering It

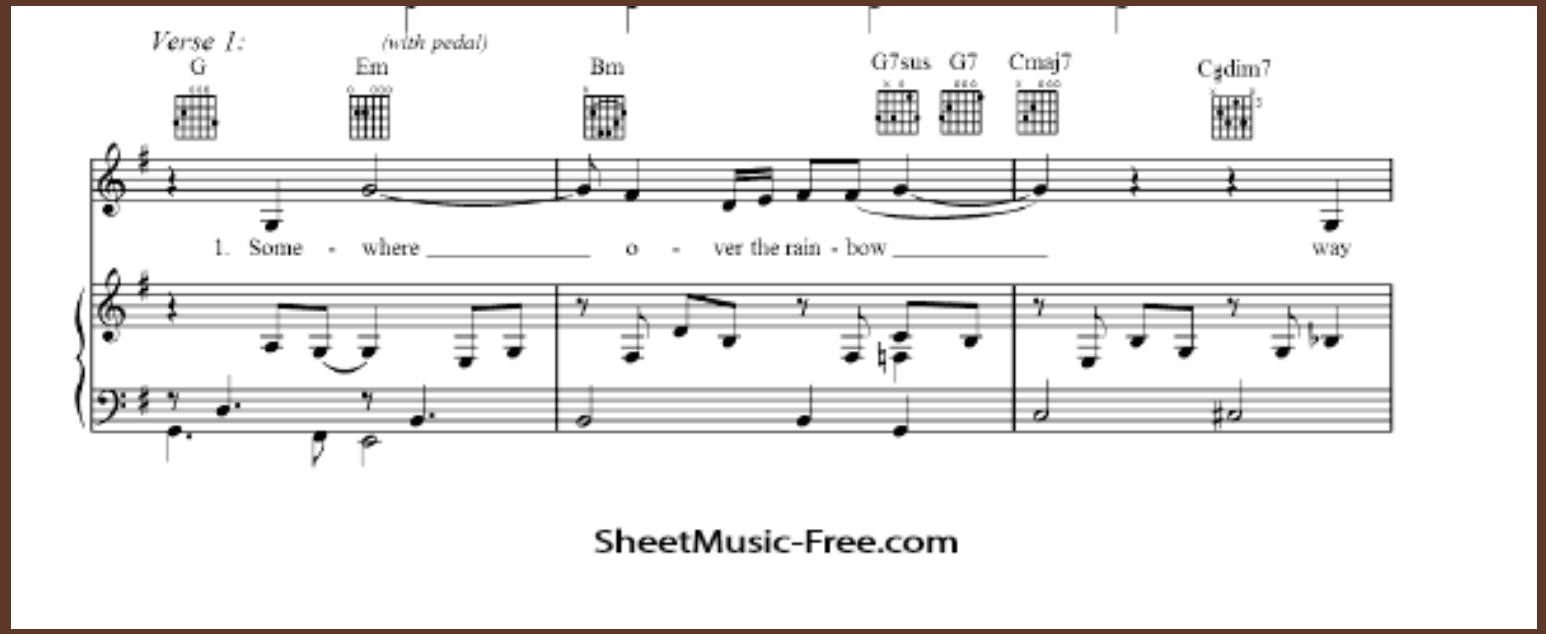
-where

2x

Some

The Octave: Remembering It

G3-> G4



Course Outline

1. Building Blocks: Some basic concepts ✓
2. Resonance: Building Sounds
3. Hearing and the Ear
4. Musical Scales
5. Musical Instruments
6. Singing and Musical Notation
7. Harmony and Dissonance; Chords
8. Combining the Elements of Music