

Traditional: 11-08

Themed: 01-08

Resonance, Harmonics, Closed/Open
Resonators & Western Musical Scales

Resonance

- Definition: When an applied force matches the natural frequency of a system
- If you've ever pushed someone on a swing, you know resonance
- If you didn't know WHEN to push the swing, you'd slow it down as often as you'd speed it up
- A swing has a natural frequency, match it and you make the swing go higher – bigger AMPLITUDE



She knows resonance!

Resonance

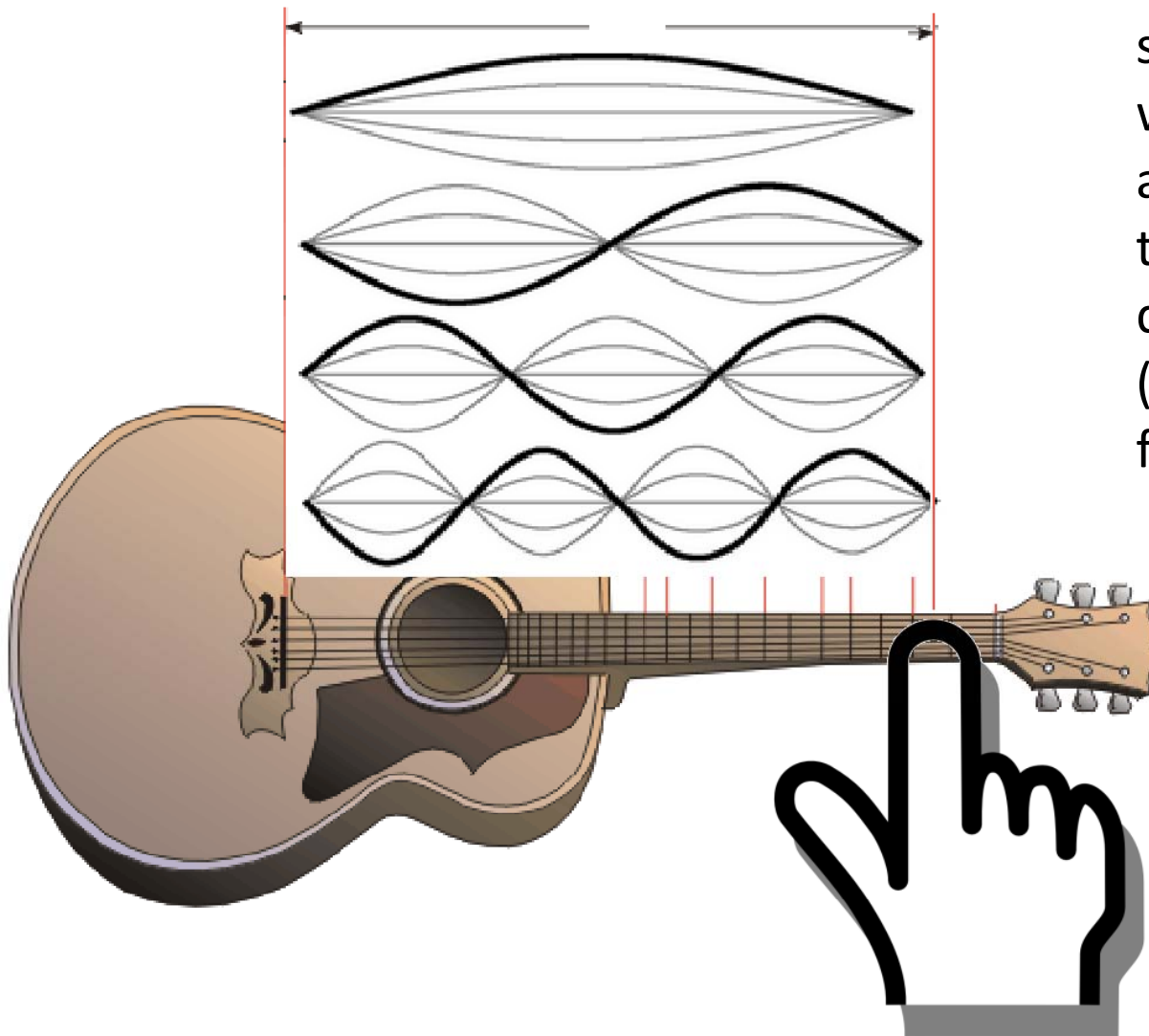
- Definition: When an applied force matches the natural frequency of a system
- Does the length of an object affect its natural vibration? Is the frequency of a longer vibrating wooden stick the same as a shorter? Prove it! (you should know this test time!)
- Do the different Orange Dilly Boppers have different NATURAL FREQUENCIES?
- Do the corresponding Dilly Boppers vibrate?
- Why would Ray Charles be bad at pushing your little brother on a swing?

Demos: Mr. Jiggly, Slinky, Orange Dilly Boppers, Paired Tuning Forks

- Goals - Can you recognize:
 - Which harmonic is being demonstrated?
 - How many nodes and antinodes?
 - How/why this is a standing wave?
 - How does resonance makes this demo possible?
 - How can you push with air and get metal to vibrate?
 - Why does one Dilly Bopper develop a big amplitude, but not the other?

Waves Notes

Sound/Doppler – Superposition Principle

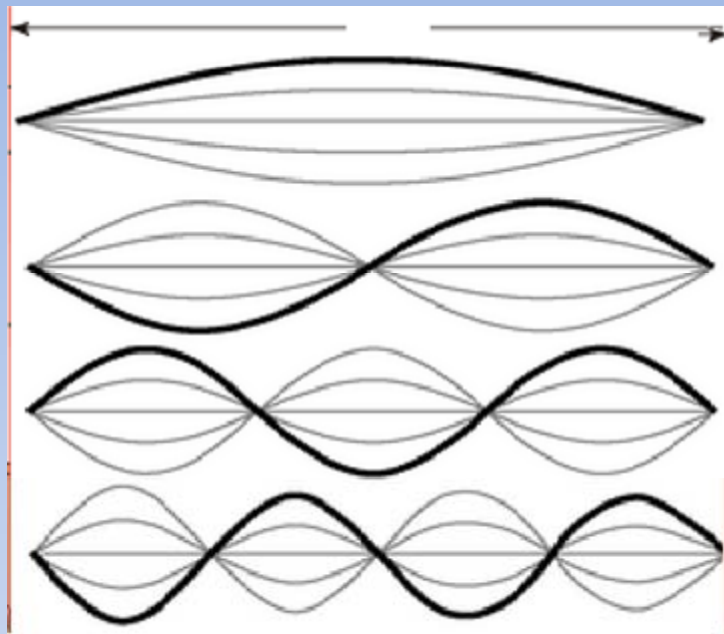


Destructive interference says that the only standing waves that will persist along a guitar string are those that don't destructively interfere (remember standing waves for the slinky)

Do you see how resonance makes only certain frequencies produced standing waves?

Harmonics are what make a musical instrument different from my tone generator. Do you see the four harmonics on the guitar?

How sound waves really “look”



First harmonic: Low frequency (dominant) called "fundamental"

Second harmonic: twice frequency

Third harmonic: 3x frequency

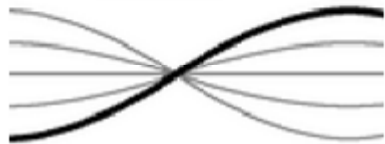
Fourth harmonic: 4x frequency

- Your voice is NOT monotone (not a tuning fork)
- Several frequencies exist simultaneously (harmonics)
 - Harmonics
 - Integer multiples of fundamental
- Most sound energy resides in fundamental
- Distributions of harmonics is “timbre”
 - Why you sound like you
 - Why a piano sounds different than a flute or guitar

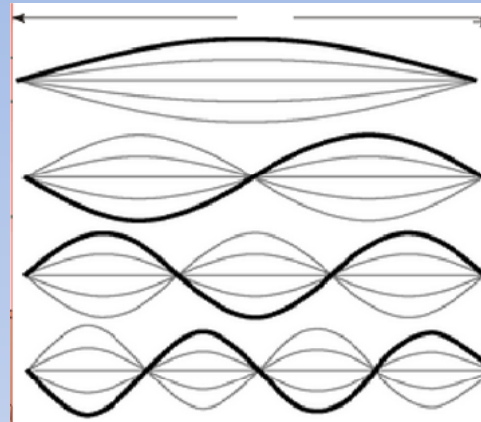
Metal Rod Demo

Metal rod

half wavelength



Full wavelength



First harmonic: Low frequency (dominant) called "fundamental"

Second harmonic: twice frequency

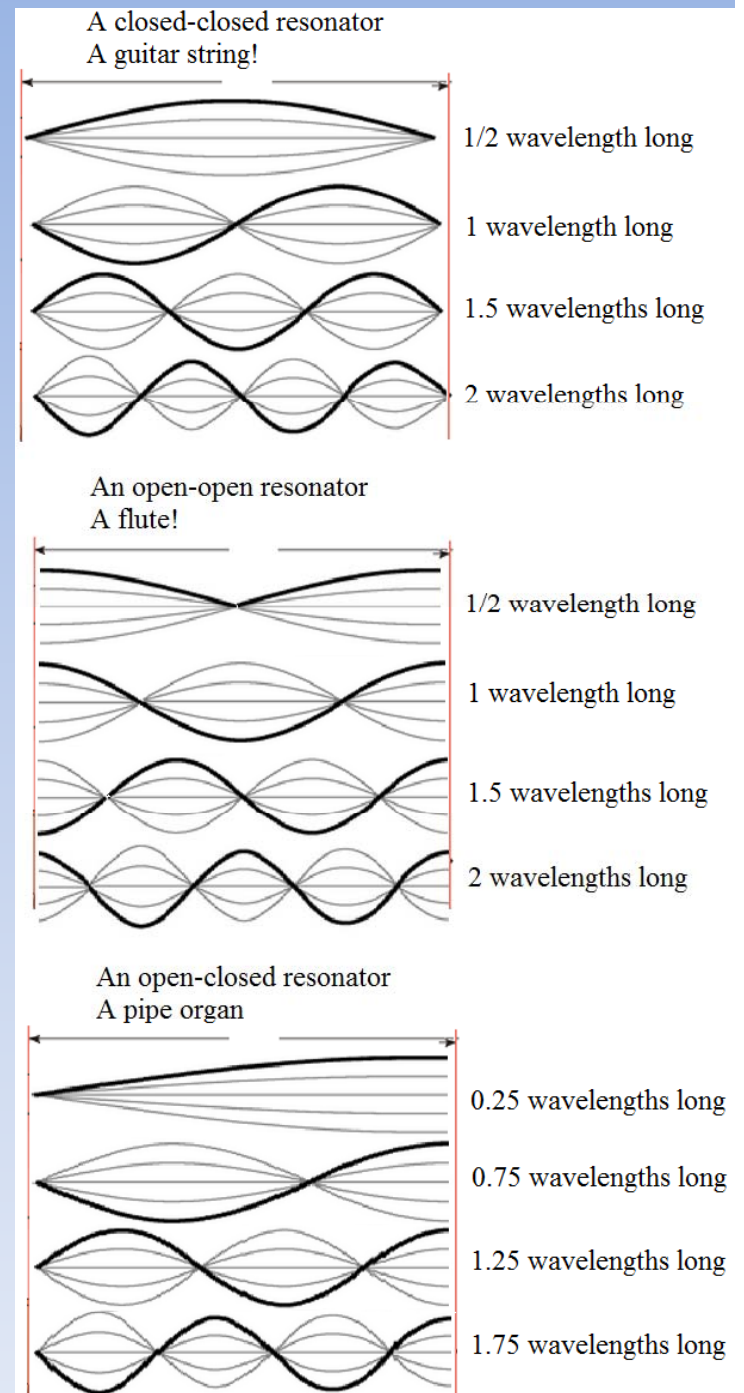
Third harmonic: 3x frequency

Fourth harmonic: 4x frequency

- Metal rod has antinodes on the ends and node in middle
 - Prove it: Clink metal rod and grab middle or end
- What is the SMALLEST wave that fits on a metal rod?
 - MUST have antinodes on ends & node in middle
- What is the next smallest wave that fits this description and the next smallest?

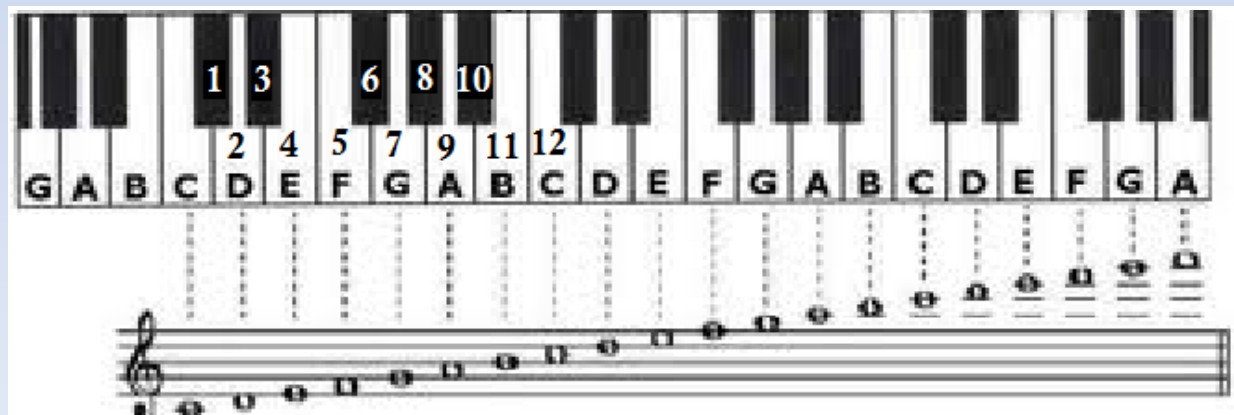
Different Resonator types (Traditional Only)

- First four harmonics shown for three resonator types.
 - Resonator types exist because of what's free to vibrate and where
 - Notice the resonator types and why
 - See why there are only certain wave lengths that vibrate?
 - Remember how there were only certain slinky frequencies that made standing waves (jumped from 1st, to 2nd to 3rd, etc.)



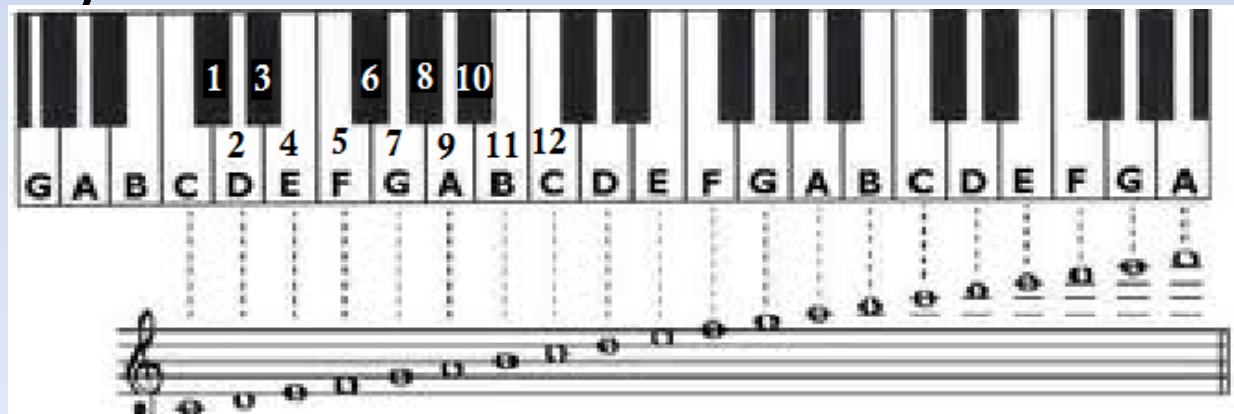
How the Western Musical Scale Works

- Rule of 72 in economics
- Each “octave” has twelve steps and within these twelve steps, the fundamental frequency double exactly
- To make something exactly double in twelve equal steps, just multiply each number by $^{12}\sqrt{2}$ (1.05946)
- This means the frequency of each of the 12 notes is 5.946% greater than the previous note



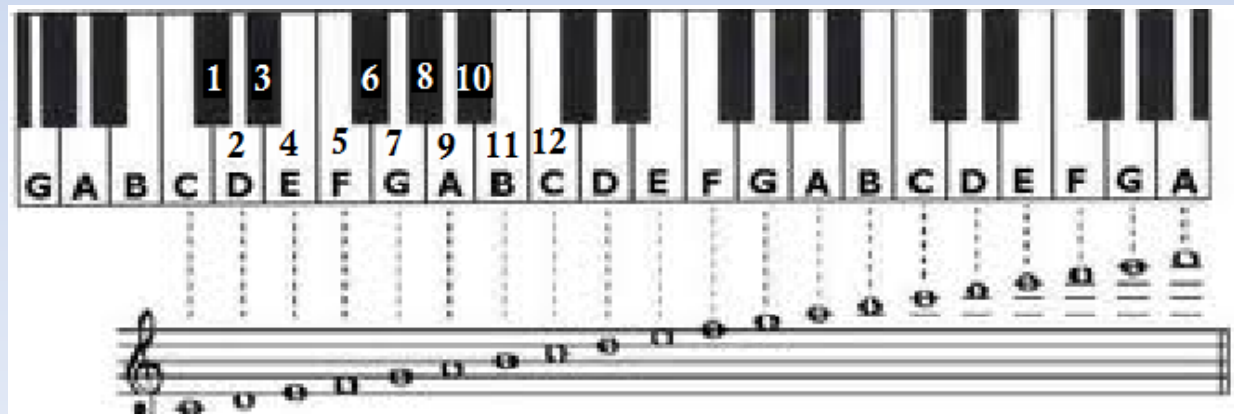
How the Western Musical Scale Works

- A4 is the 4th octave of A and is 440 Hz
- A3 is the third octave of A and is 220 Hz
- What the fundamental frequency of A2? A1?
A5?
- Harder: If A4 is 440 Hz, what's the fundamental frequency for C5 (3 keys right)?
(523 Hz)
- E5? (587 Hz)



How the Western Musical Scale Works

- If 110 Hz is A₂ and is the fundamental frequency of a piano string what are the 2nd, 3rd, 4th harmonics?
- Which of these represent notes A at some octave?
- You don't want to be that person that confuses octaves with harmonics, see how they're different?



How a guitar amplifies sound

- Guitar strings are very thin
- Alone a guitar string would knife through the air and wouldn't vibrate enough air to make a very audible sound
- Attached to a sound board, the large surface area of the board moves a lot more air, enough to be easily audible

