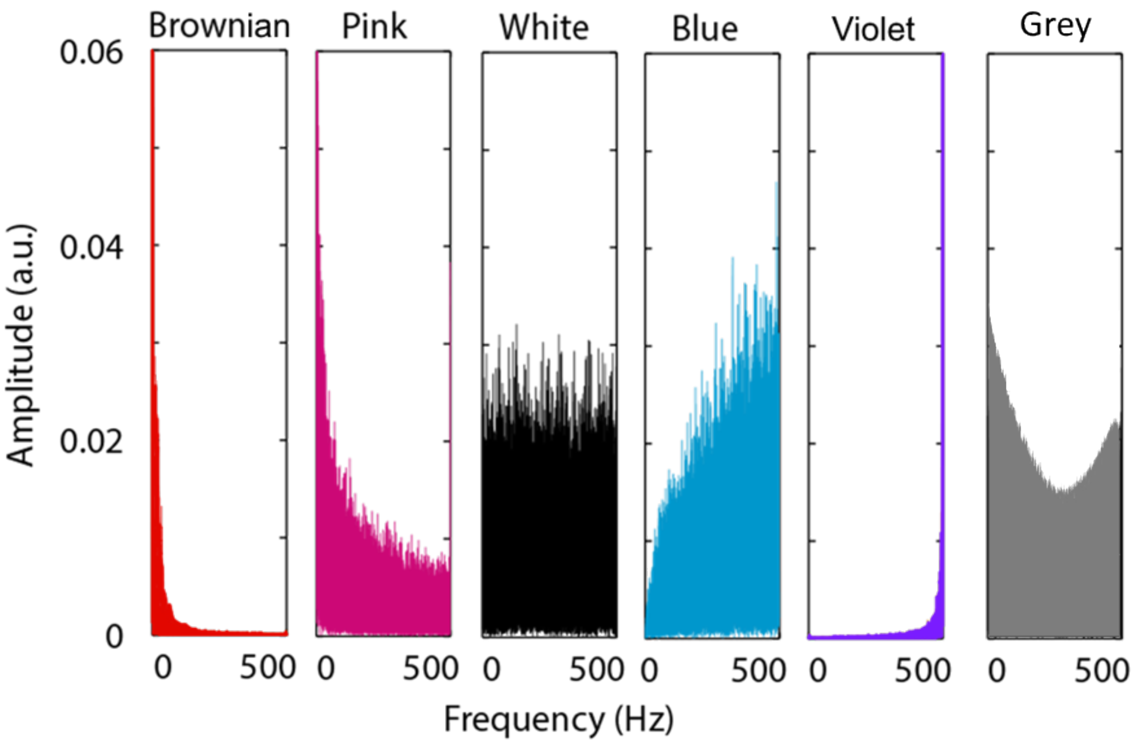
Physics 1240: Sound and Music

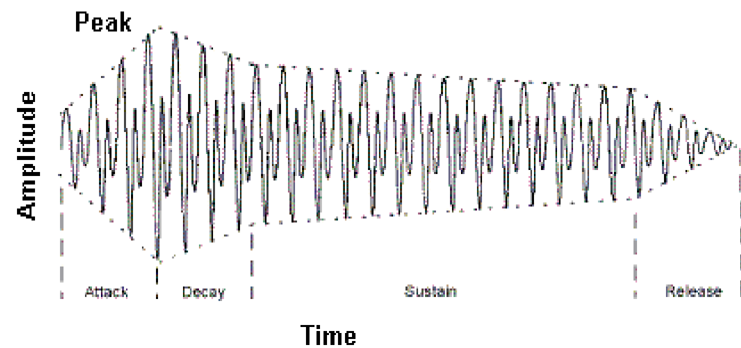
Today (7/24/19): Vibrating Strings, Keyboard Instruments

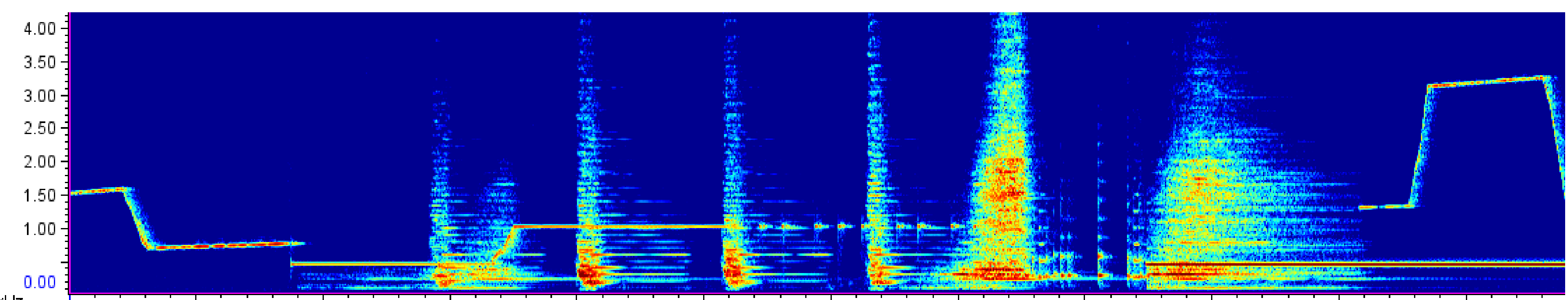
Next time: Vibrating Air Columns, Organs

Student performance:
flamenco/classical guitar

Review


Brownian
Pink
White
Blue
Violet
Grey
0.06
0.04
0.02
0
Amplitude (a.u.)
0
500
Frequency (Hz)

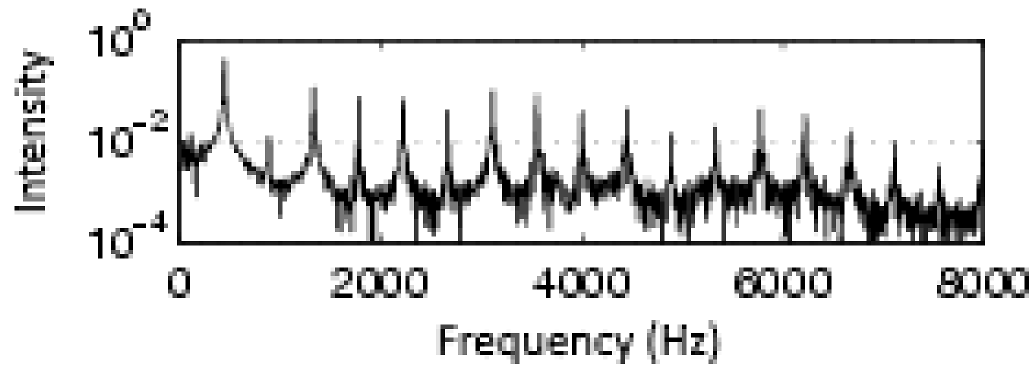

Peak
Amplitude
Attack
Decay
Sustain
Release
Time


4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.00

BA

Clicker Question 10.1

What instrument could produce the plot shown below?



A) Maracas
B) Snare drum
C) Violin
D) Multiple of these
E) None of these

BA

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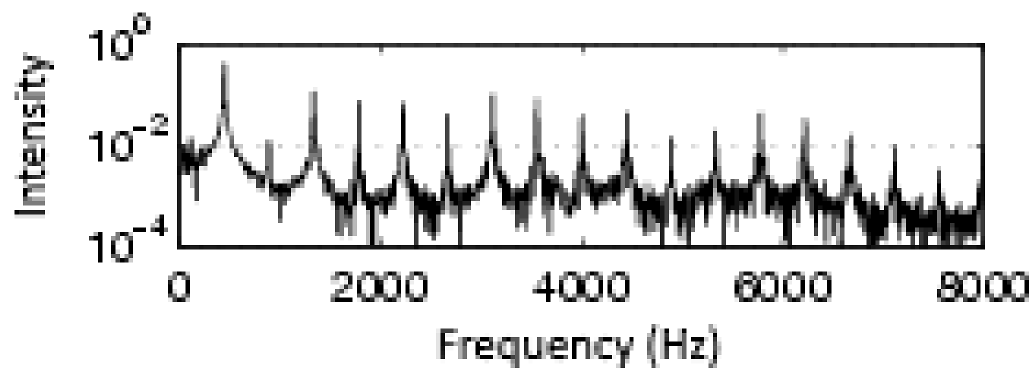
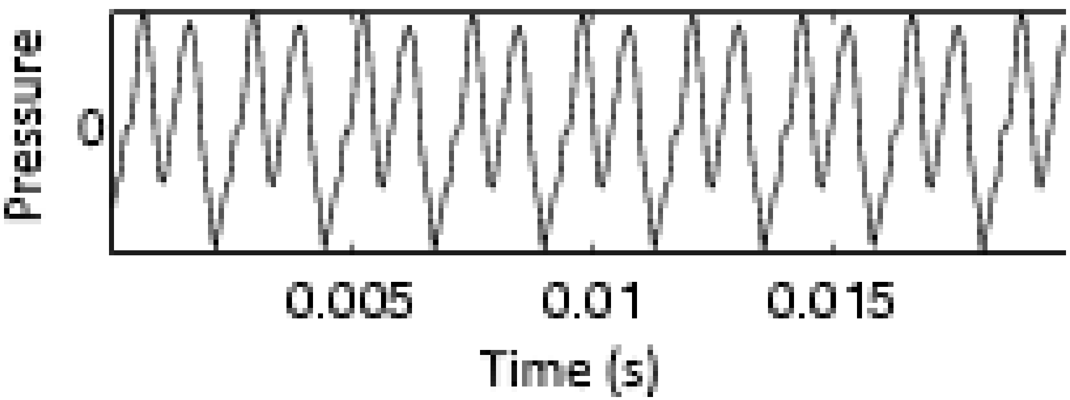


BA

Clicker Question 10.2

What sound could produce the plot shown below?

A) Waterfall
B) Tuning Fork
C) Triangle Wave
D) Ticking clock
E) Flute



BA

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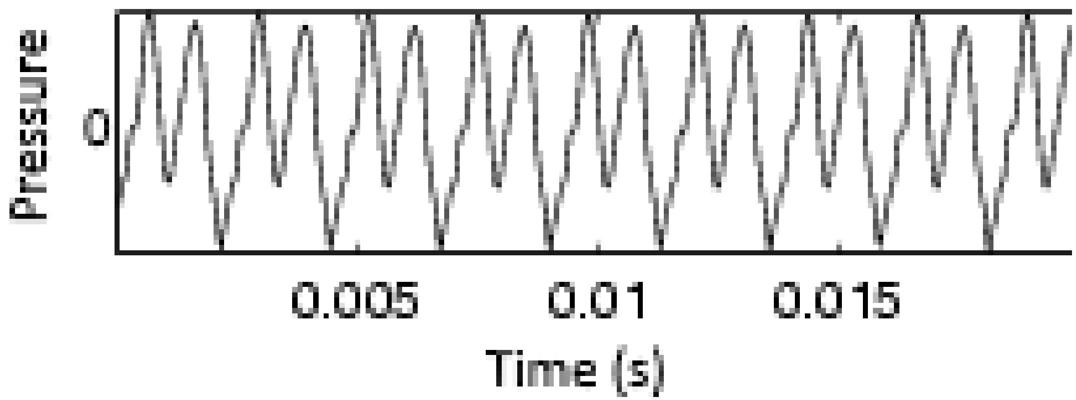
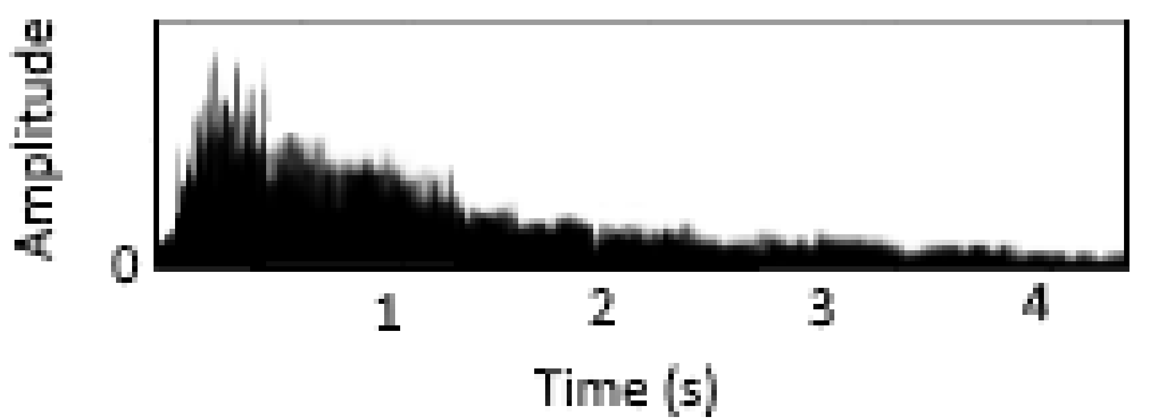


BA

Clicker Question 10.3

What sound could produce the plot shown below?

A) Cymbal crash
B) Waterfall
C) Saxophone
D) Drum keeping time
E) Multiple of the above



BA

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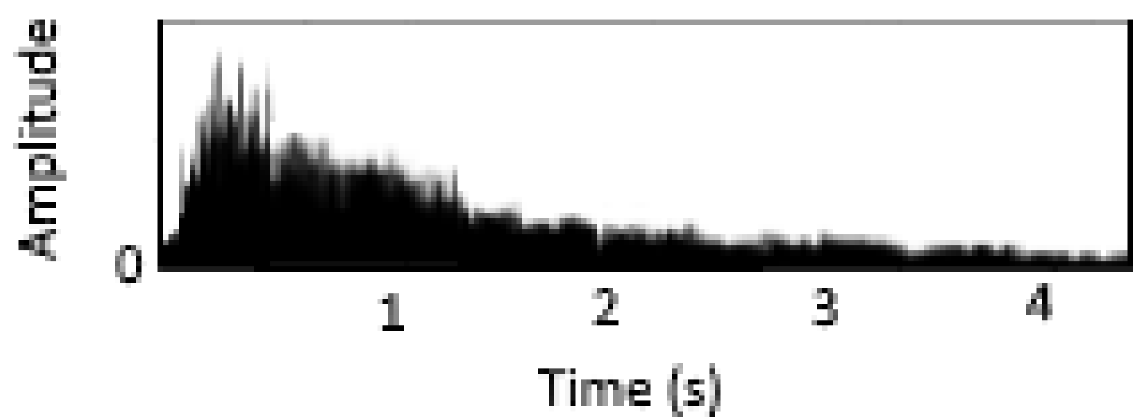
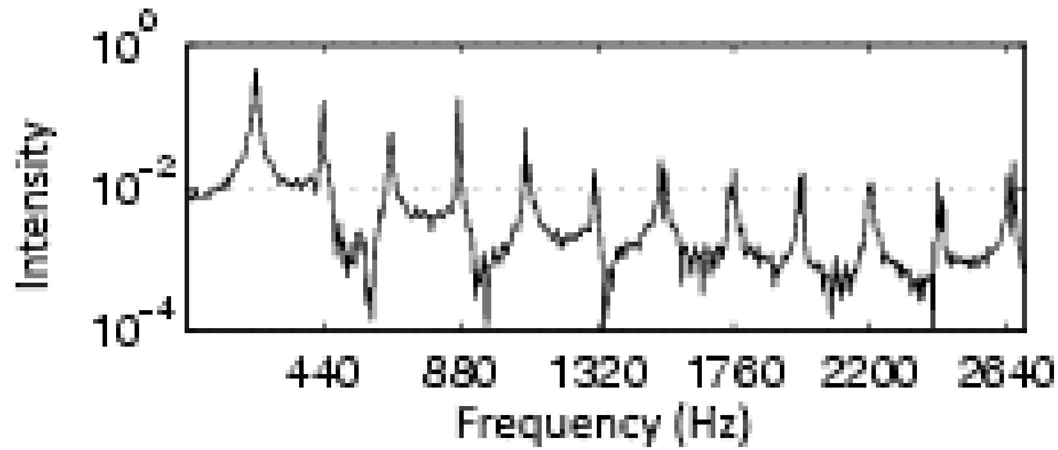


BA

Clicker Question 10.4

What note is being played on the piano to produce the plot below?

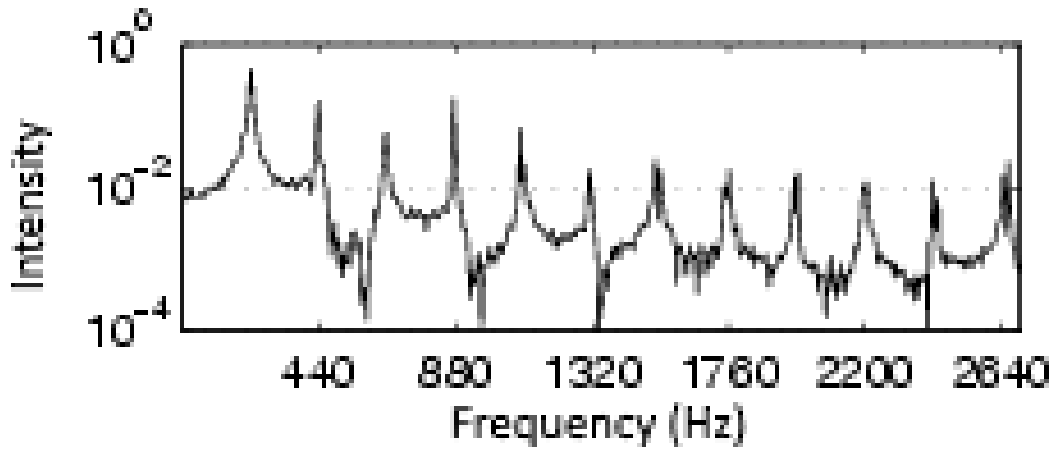


A) A_3 (220 Hz)
B) A_4 (440 Hz)
C) A_5 (880 Hz)
D) E_7 (2640 Hz)
E) This can’t be a note on a piano

BA

Clicker Question 10.4

What note is being played on the piano to produce the plot below?



A) A_3 (220 Hz)
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Types of Instruments

(Hornbostel–Sachs classification)

- Chordophones: vibrating strings

- Aerophones: vibrating columns of air

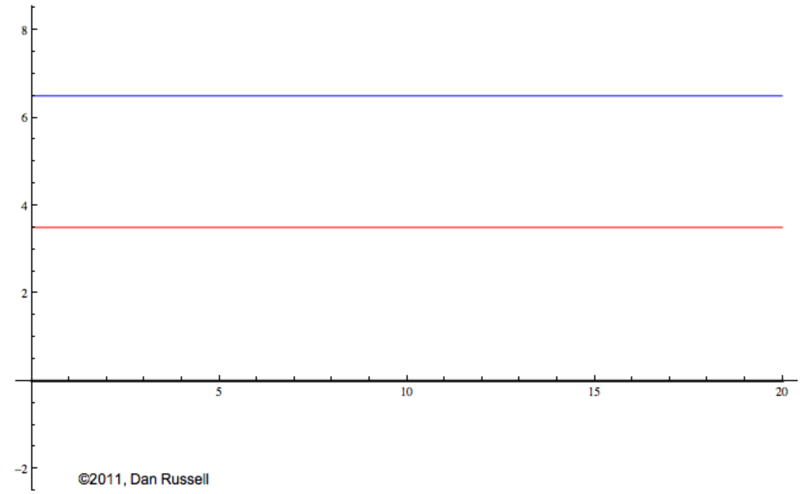
- Membranophones: vibrating membrane/skin

- Idiophones: vibrating the whole instrument

- Electrophones: vibrating loudspeaker

Vibrating Strings

Reflection of wave pulse from hard boundary



Two waves travelling in opposite directions

Vibrating Strings

- For the nth harmonic,

$$L = n\left(\frac{\lambda}{2}\right)$$

- Recall: $v = \lambda f$

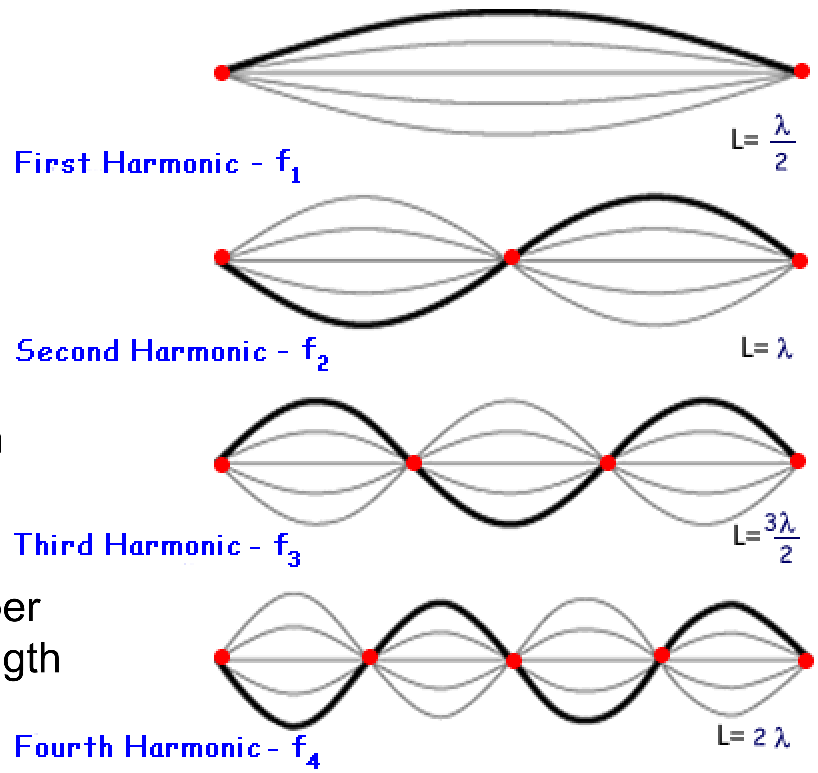
$$\Rightarrow \quad f_n = n\left(\frac{v_t}{2L}\right)$$

- New formula: $v_t = \sqrt{\frac{T}{m/L}}$

tension

mass per unit length

$$\boxed{f_n = \frac{n}{2L}\sqrt{\frac{T}{m/L}}}$$



Vibrating Strings

$$f_n = \frac{n}{2L}\sqrt{\frac{T}{m/L}}$$

- Now we have 4 ways to change the pitch of a string:
  - Change length (*L*) - e.g. Harp
  - Change density/“gauge” (*m/L*) - e.g. Cello
  - Change harmonic number (*n*) - e.g. Guitar
  - Change tension (*T*) - e.g. Đàn Bầu

BA

Clicker Question 10.5

What will increase the frequency of a guitar string the most?

A) Doubling the string's mass per unit length
B) Decreasing the mass per unit length by a factor of 2
C) Doubling the string's length (using the same material)
D) Decreasing the length by a factor of 2 (using the same material)
E) Doubling the tension

BA

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BA

Clicker Question 10.6

If the strings of the harp below were strummed from left to right, what would you hear?

A) Increasing pitch ("upward glissando")
B) Decreasing pitch ("downward glissando")
C) Same pitch throughout

BA

Clicker Question 10.6

If the strings of the harp below were strummed from left to right, what would you hear?

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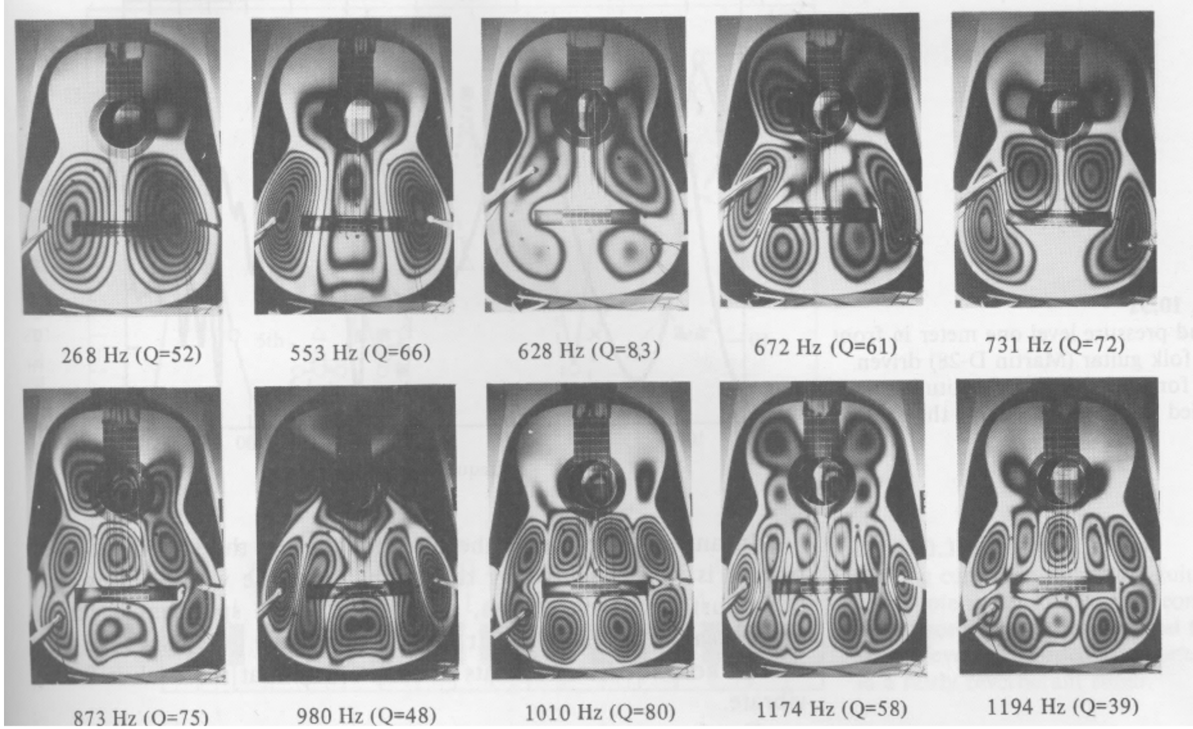
C) Same pitch throughout

Chordophones

- Most chordophones have more than just strings – why?
- Resonating body: amplifies sound created by strings

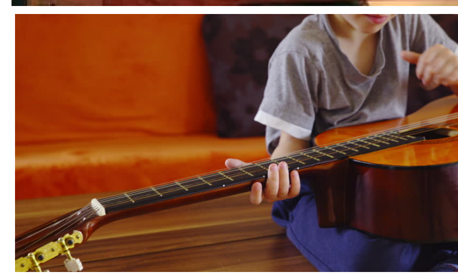


Chordophones

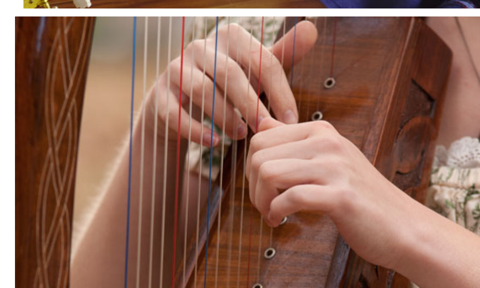
- Most chordophones have more than just strings – why?
- Resonating body: amplifies sound created by strings
- Three types of chordophones:

    1. Zithers: strings parallel to resonator along full length

    2. Lutes: strings parallel to resonator at one end



    3. Harps: strings perpendicular to resonator



Chordophones

- How to create standing waves on a string?

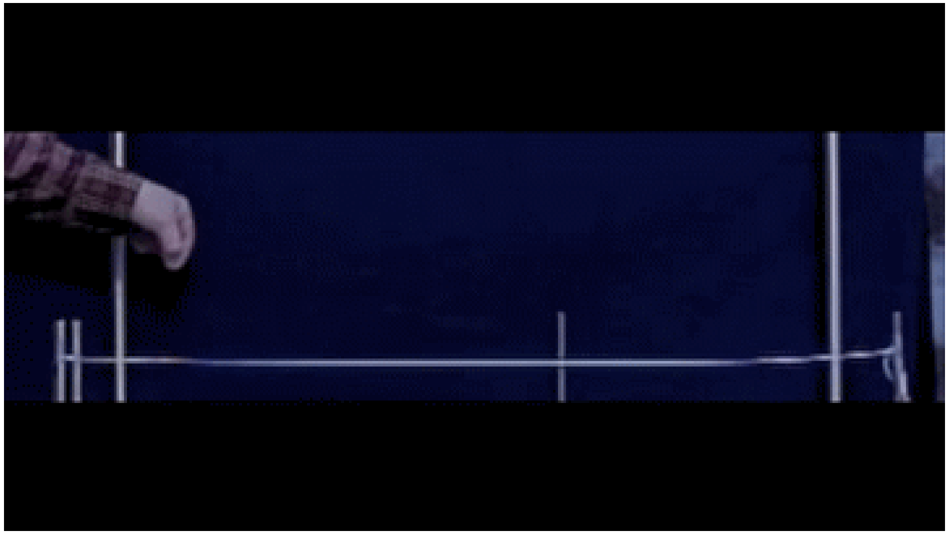
  1. Provide initial displacement (“plucking”)

  2. Provide initial velocity (“striking”)

  3. Provide initial displacement AND velocity (“bowing”)

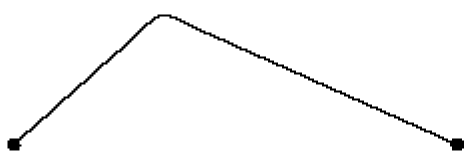
Plucking

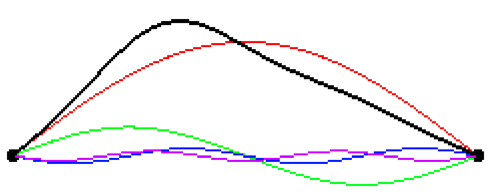
- Wave pattern depends on location the string is plucked
- What happened to the standing waves?

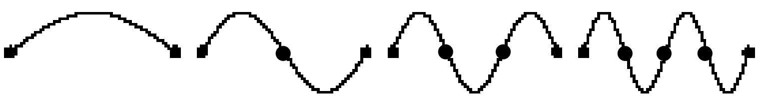


Plucking

- Fourier's theorem (many harmonics are present in one sound)
- Standing wave pattern with a **node** at a plucked point will not be sounded





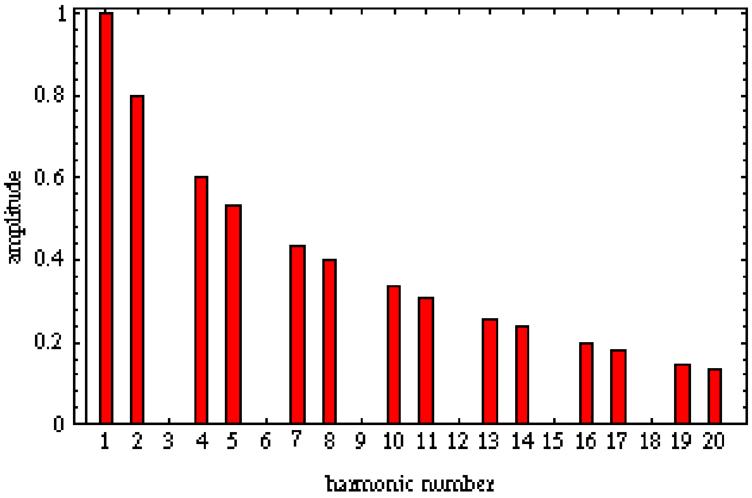


BA

Clicker Question 10.7

The spectrum below shows the harmonics of standing waves of a plucked string. How far from the edge of the string was it plucked?

A) Right at the edge
B) In the middle
C) 1/3rd of the way from the edge
D) 1/4th of the way from the edge
E) 1/6th of the way from the edge



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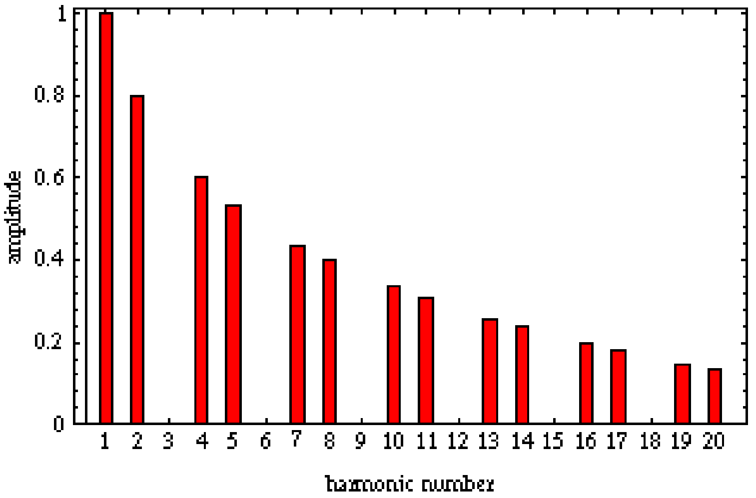
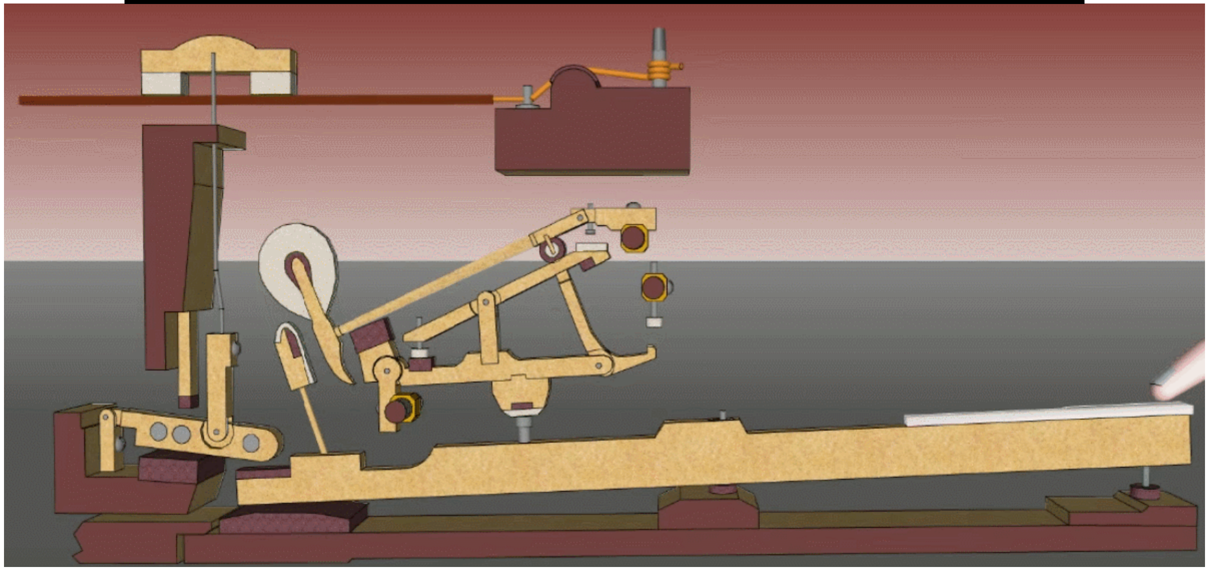


Striking

- Depends on the location the string is touched
  - Striking the antinode of a harmonic will emphasize that harmonic
  - Striking the node of a harmonic will cause it to disappear from the spectrum
- Depends on velocity with which the string is struck
  - Higher velocity means larger amplitude (greater volume)

Piano



Piano

Upright vs grand

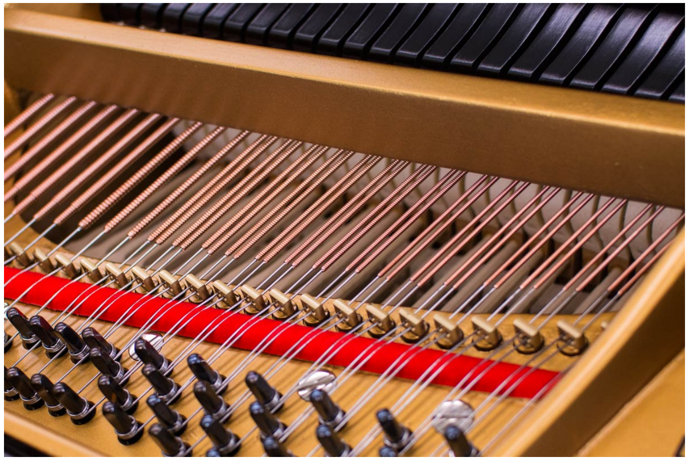
Pedals:
left ("soft")
vs right
("sustain")

Piano

- Inharmonicity: when the frequencies of a sound above the fundamental are not exactly integer multiples of the fundamental

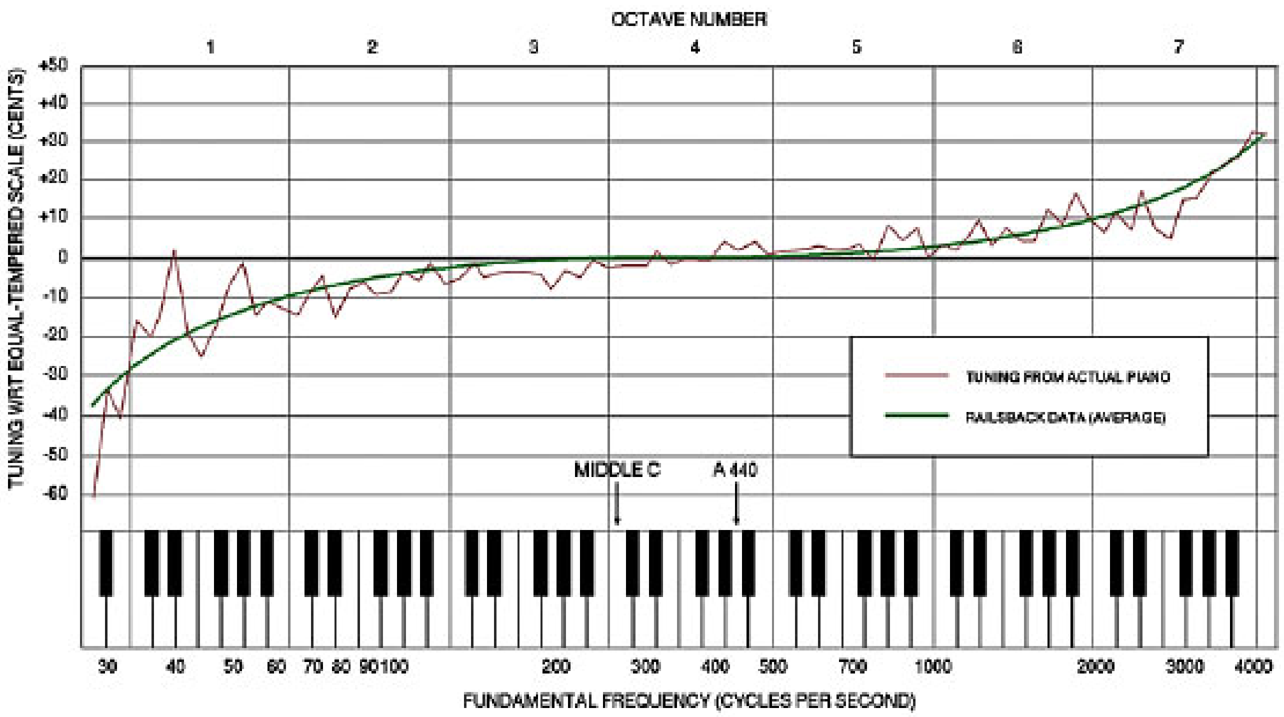
- Modes/Partials: general term for the set of frequencies present in a spectrum (="harmonics" when they are integer multiples of the fundamental)

- For piano: progressively higher partials are stretched more (e.g. $f, \quad 2.01f, \quad 3.02f, \quad 4.04f, \ldots$) (metal in wires provides resistance to wave propagation)



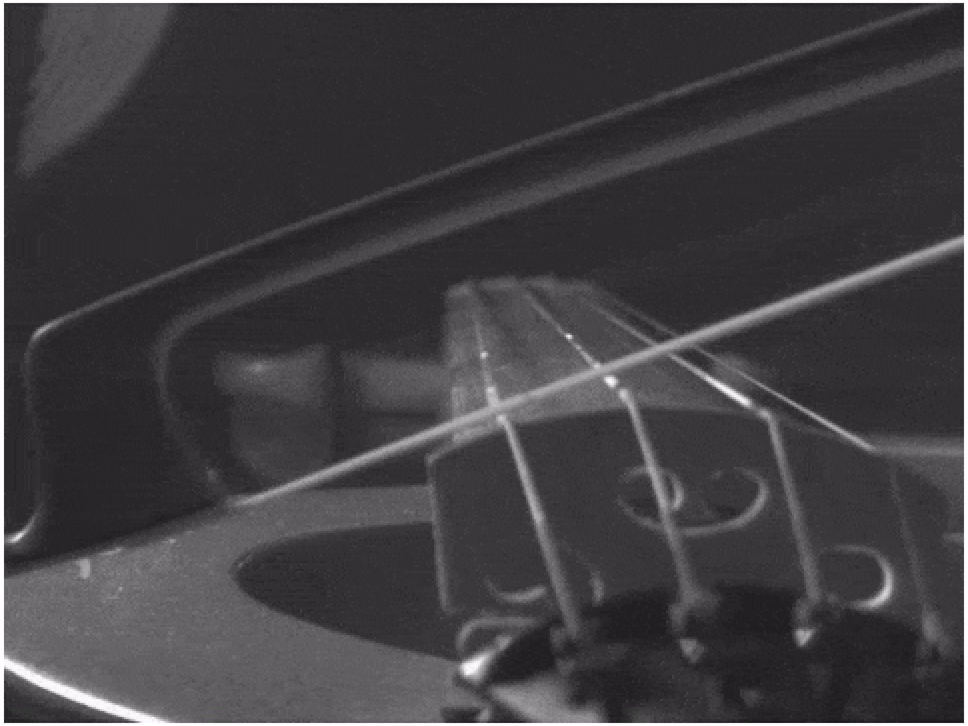
Piano – Octave Stretching

- Lower and higher octaves are stretched slightly out of tune to compensate for inharmonicity



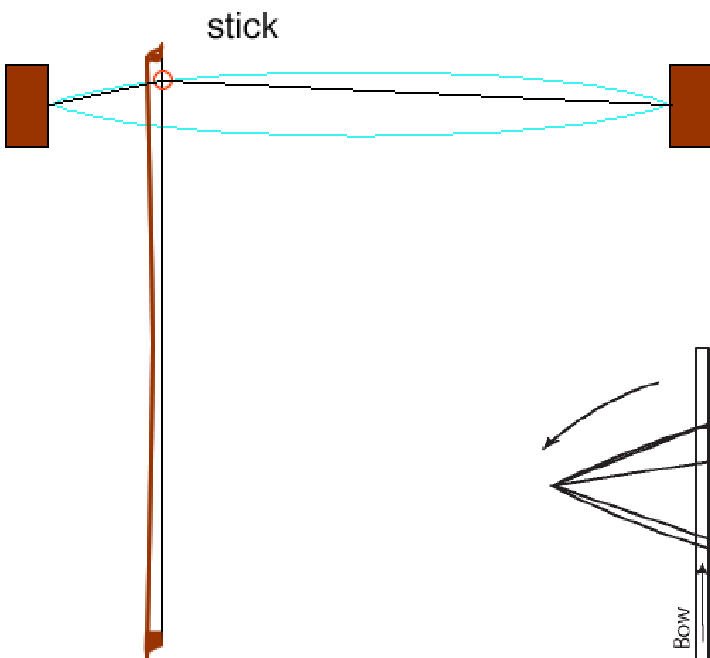
<u>Bowing</u>

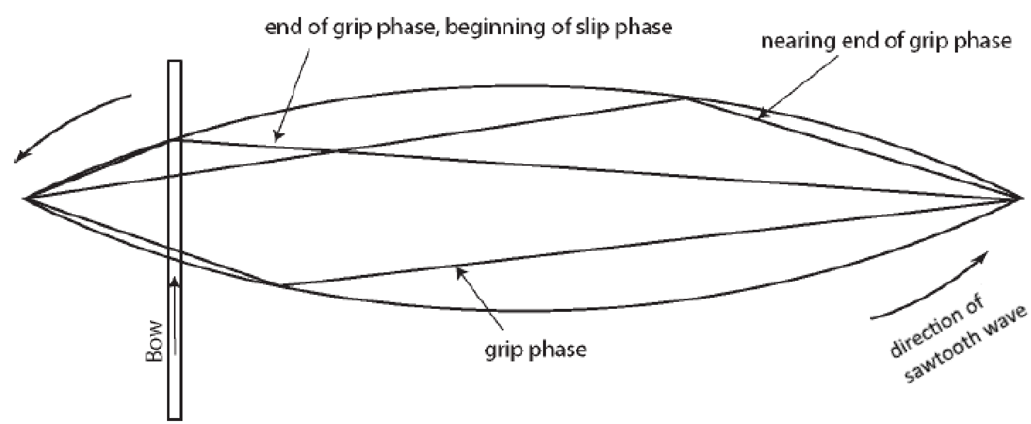
- <u>Slip-grip mechanism</u>: fast slip, slow grip
- Sawtooth wave



Bowing

- Slip-grip mechanism: fast slip, slow grip
  (a.k.a. "Helmholtz motion")

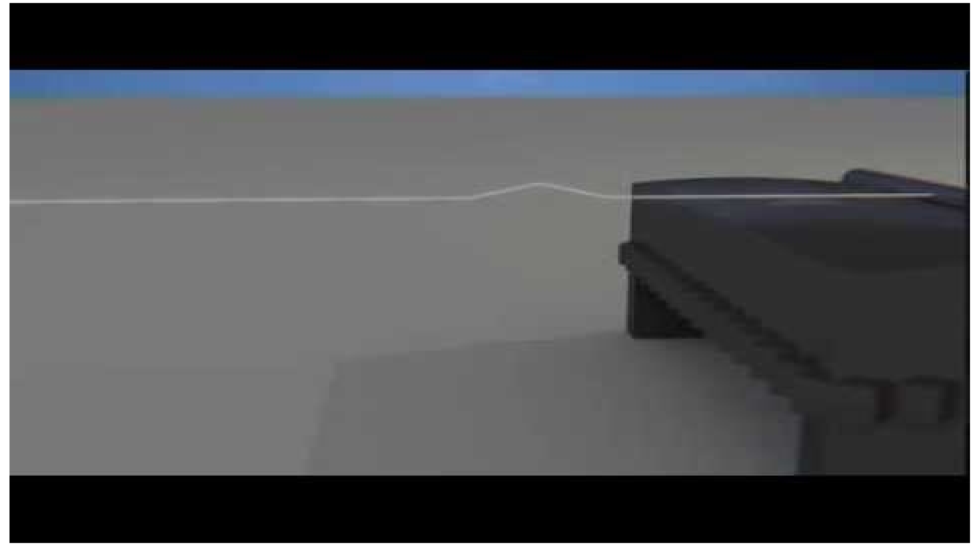




Hurdy-Gurdy

- Sitar

Helmholtz Motion



- Tanpura