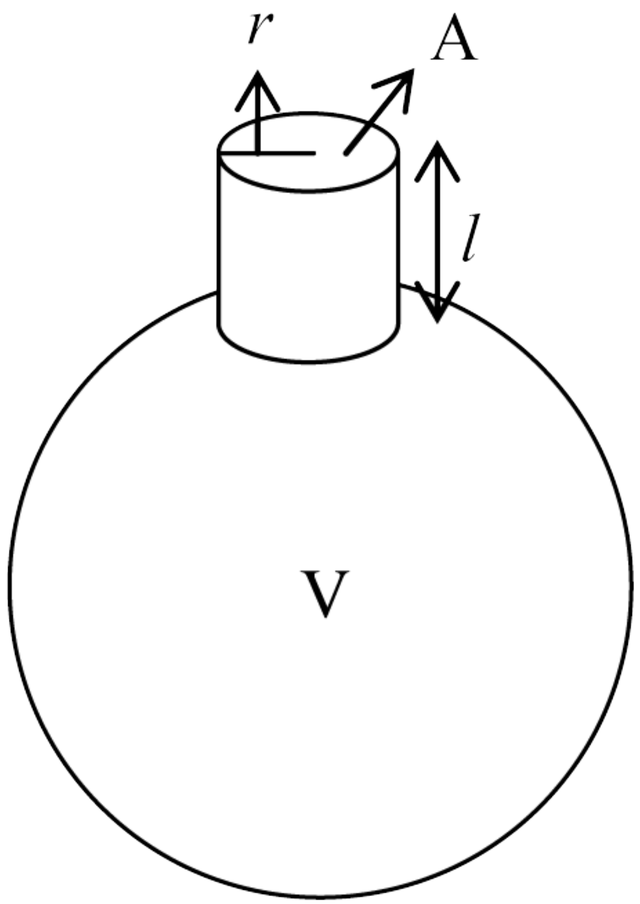
Helmholtz resonator



$$f = \frac{v}{2\pi}\sqrt{\frac{A}{l_{\text{eff}}V}}$$

- Example:

$r = 1\ \text{cm}\,,\ l = 2.7\ \text{cm}\,,\ V = 425\ \text{mL}\,,\ v = 346\ \text{m/s}$

$A = \pi r^2\,,\ 1\ \text{mL} = 10^{-6}\ \text{m}^3 \quad \Rightarrow \quad f = 239\ \text{Hz}$

4. Fourier analysis & synthesis

Fourier's theorem

- **standing wave vibrations** are the **"building blocks"** for any complex vibration
- any complex periodic wave can be written as a **sum of harmonics**:

$$y(t) = A_1 \sin(2\pi f_1 t + \phi_1) + A_2 \sin(2\pi f_2 t + \phi_2) + \cdots$$

$$f_N = N f_1, \qquad N = 1,2,\cdots$$

- **Ohm's law of hearing**: Phases have little effect on the timbre of the sound
- **Fourier analysis**: decomposing a complex periodic wave into its contributing harmonics
- **Fourier synthesis**: constructing a complex periodic wave by combining harmonics

5. String instruments

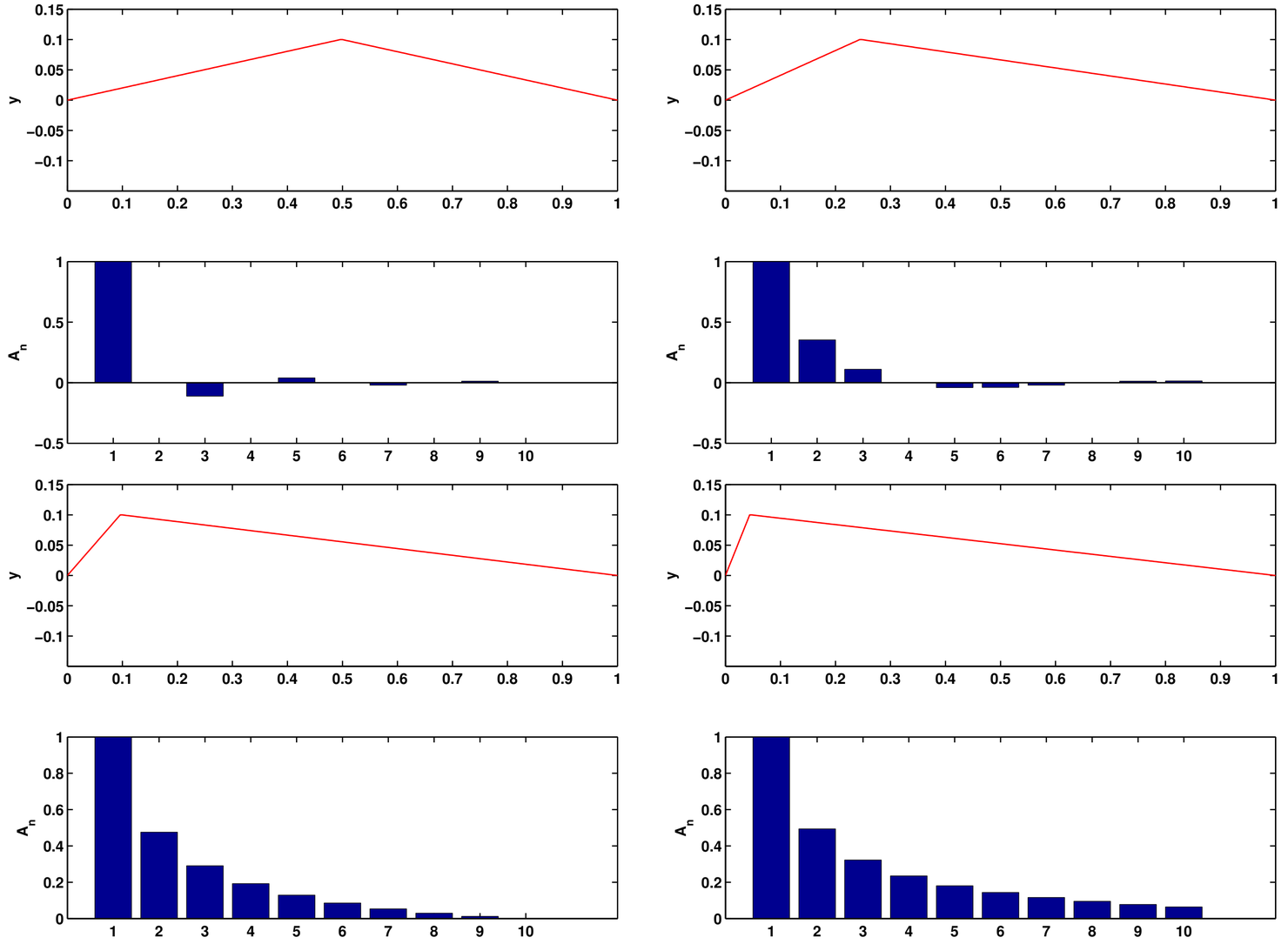
Plucked versus bowed strings

- Plucked string: https://www.youtube.com/watch?v=_X72on6CSL0
- Bowed string: https://www.youtube.com/watch?v=6JeyiM0YNo4
- iPhone guitar video: https://www.youtube.com/watch?v=TKF6nFzpHBU

- NOTE: the iPhone guitar video does not show the wave pulses on the strings as they really are. Rather one sees multiple images of the same pulse shape on the string due to the "rolling shutter" effect of the iPhone camera. The actual pulses on a guitar string behave as shown in the first video.

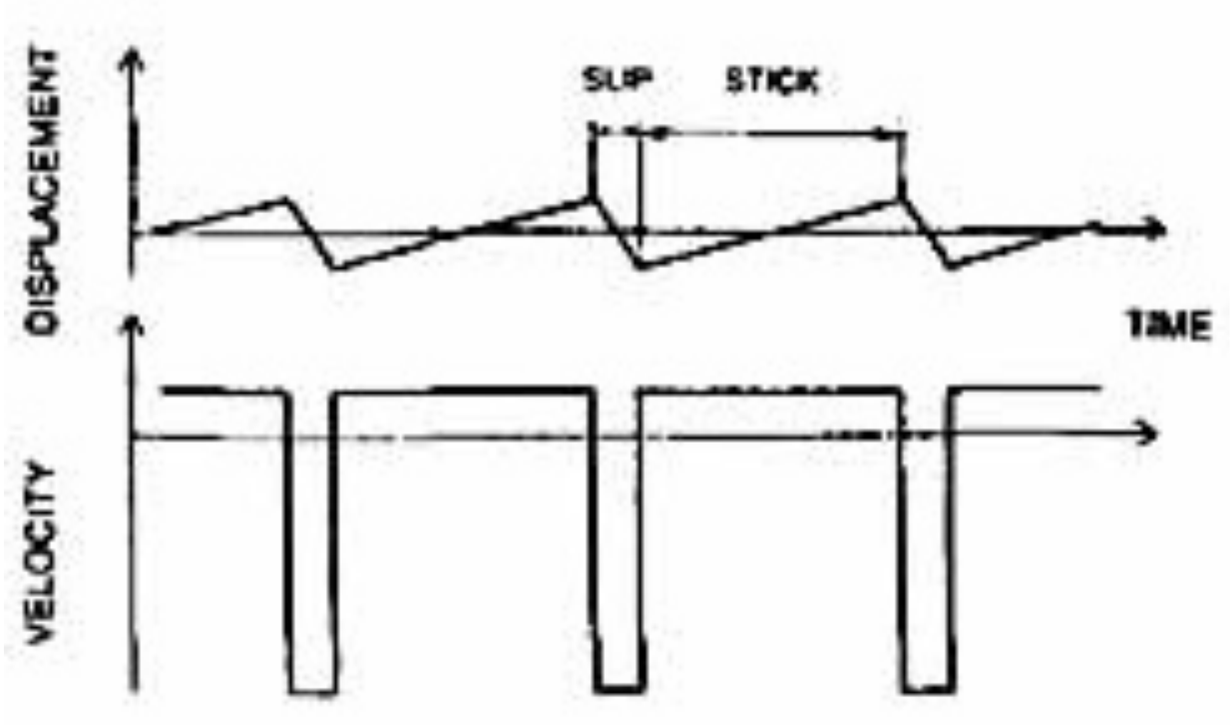
Fourier coefficients of a plucked string

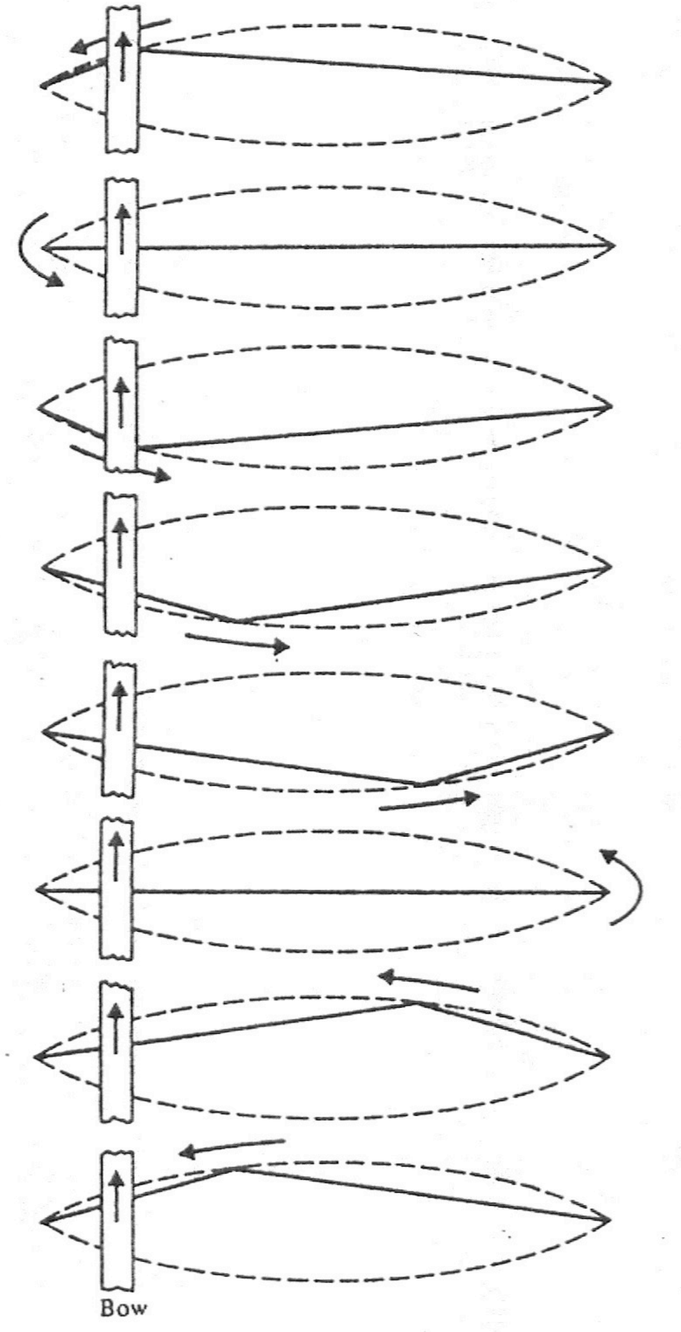
- Sounds are **richer** when the string is plucked **closer to the bridge**
- If the string is plucked in the **middle**, there at **no even harmonics**



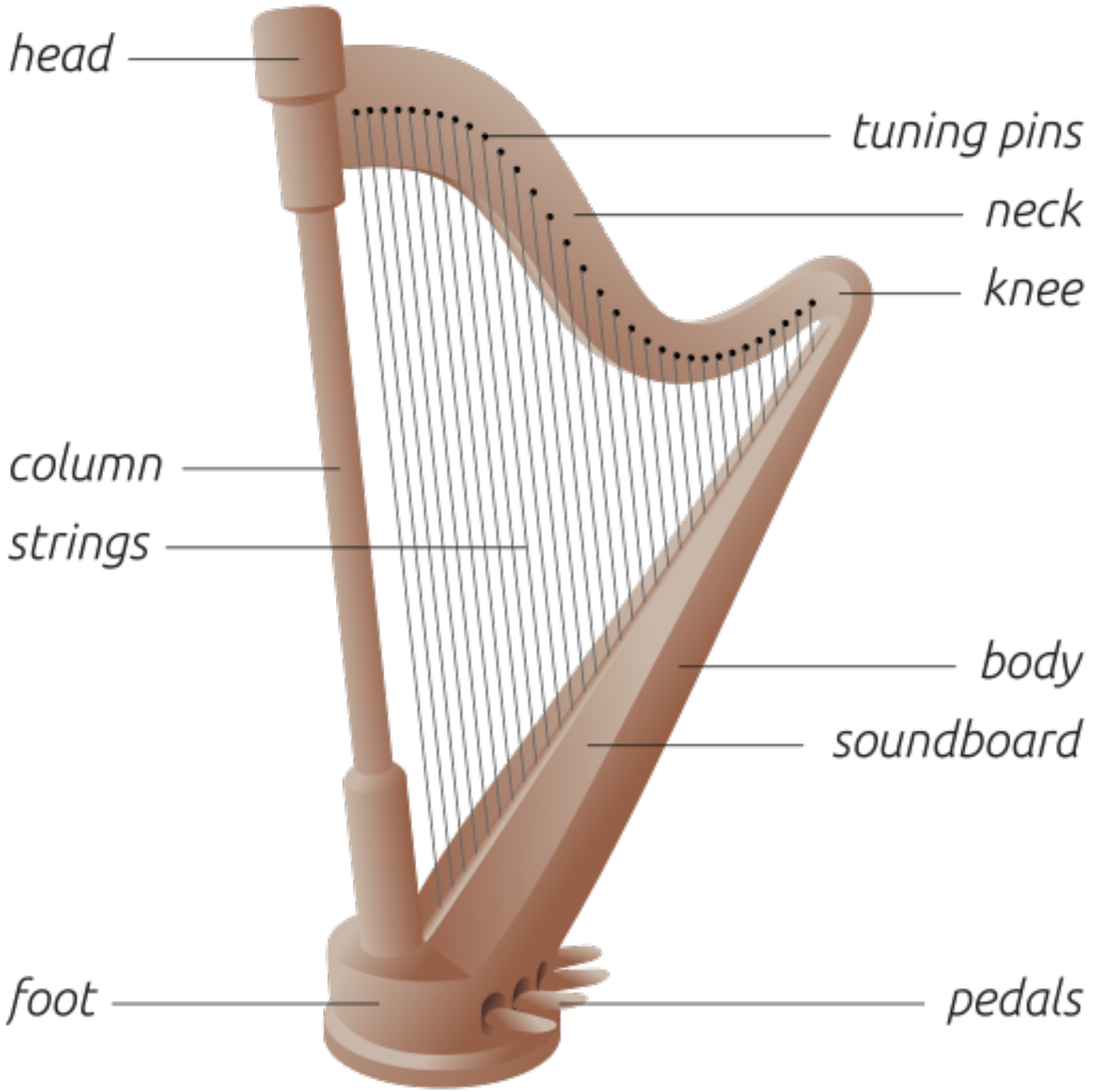
Stick-slip motion of a bowed string

- The violin string alternately “sticks” and then “slips” against the bow hundreds of times per second

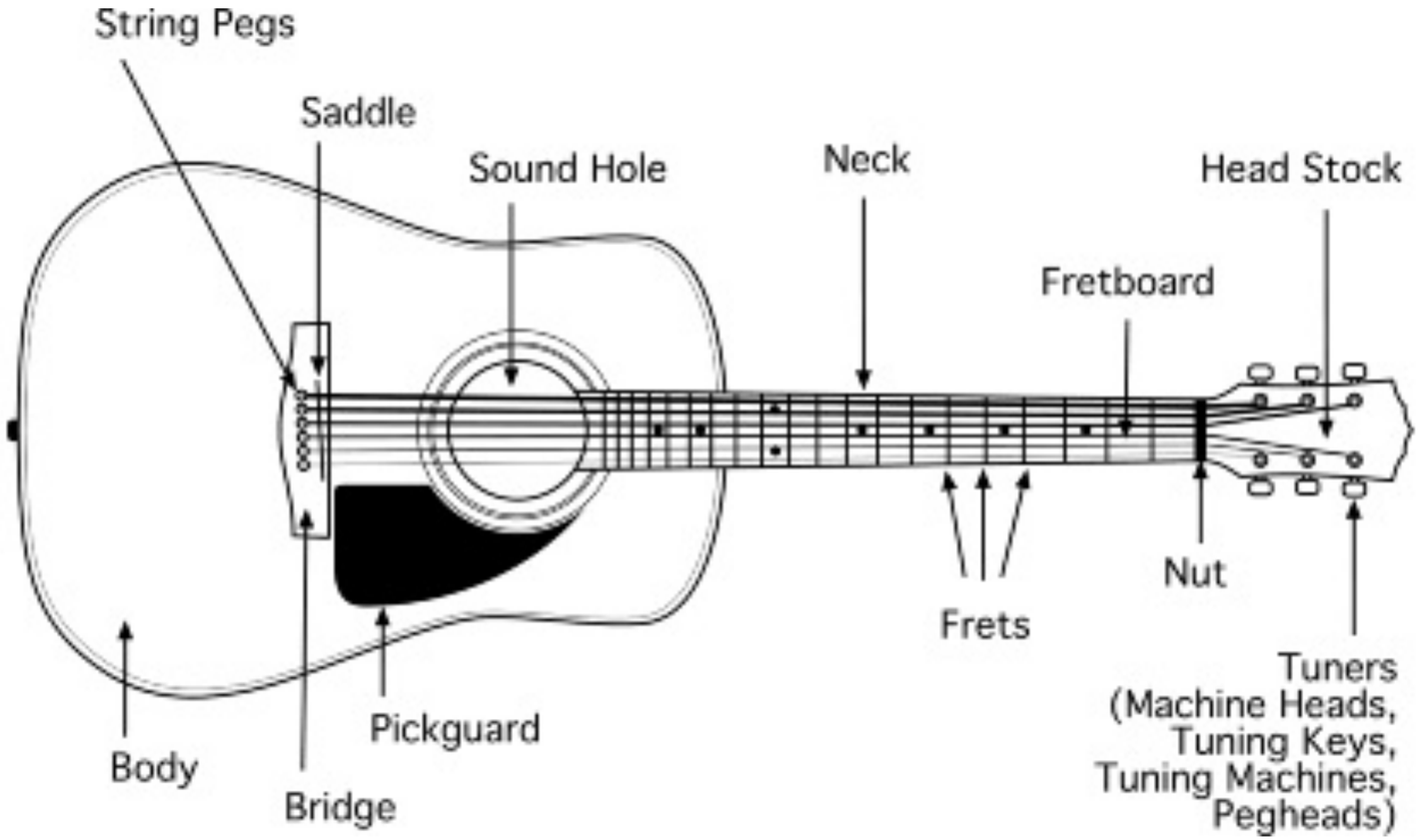




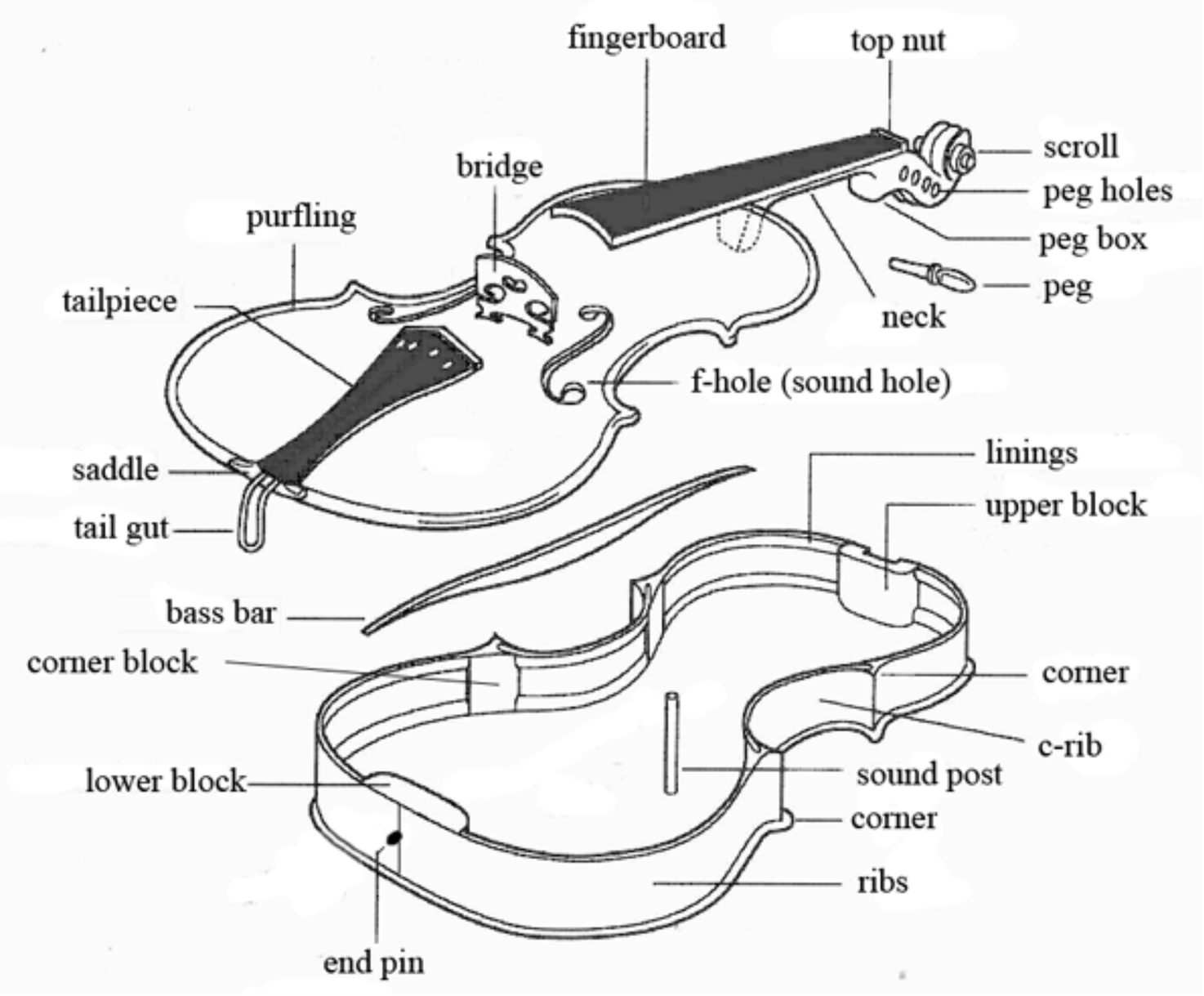
Harp


head
tuning pins
neck
knee
column
strings
body
soundboard
foot
pedals

Guitar

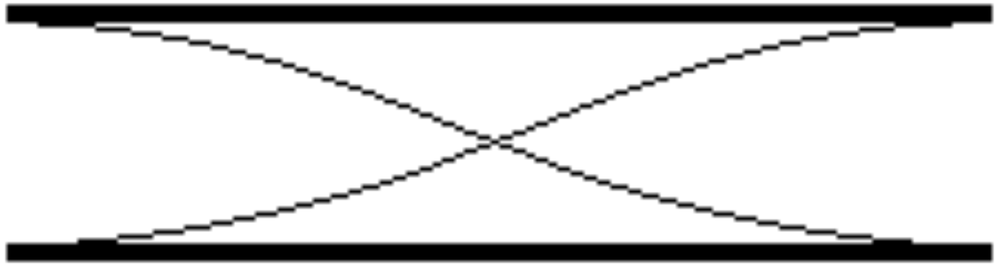

String Pegs
Saddle
Sound Hole
Neck
Head Stock
Fretboard
Nut
Frets
Tuners
(Machine Heads,
Tuning Keys,
Tuning Machines,
Pegheads)
Pickguard
Body
Bridge

Violin


fingerboard
top nut
scroll
bridge
peg holes
purfling
peg box
peg
tailpiece
neck
f-hole (sound hole)
saddle
linings
tail gut
upper block
bass bar
corner block
corner
c-rib
lower block
sound post
corner
ribs
end pin

6. Wind instruments

Open and closed tubes (recall previous discussion)



$$\lambda_N = \frac{2L}{N} \qquad f_N = Nf_1 \qquad f_1 = \frac{v}{2L} \qquad N = 1,2,\cdots$$

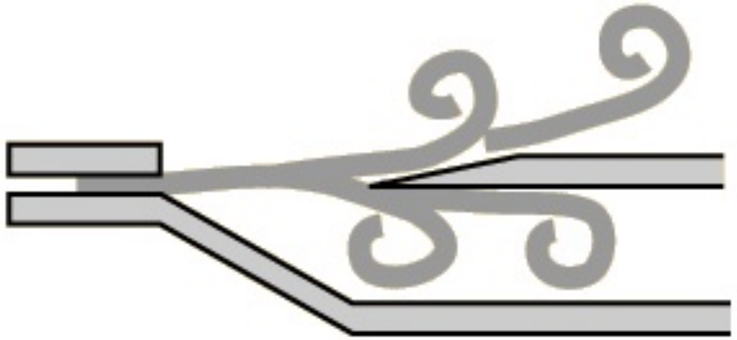
(both even and odd harmonics)

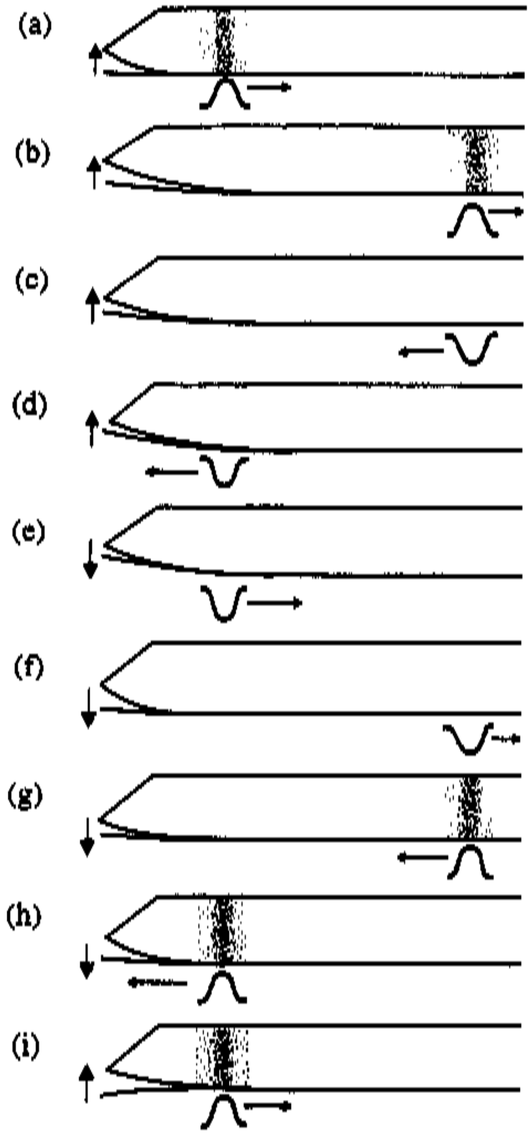
$$\lambda_N = \frac{4L}{N} \qquad f_N = Nf_1 \qquad f_1 = \frac{v}{4L} \qquad N = 1,3,5,\cdots$$

(only odd harmonics)

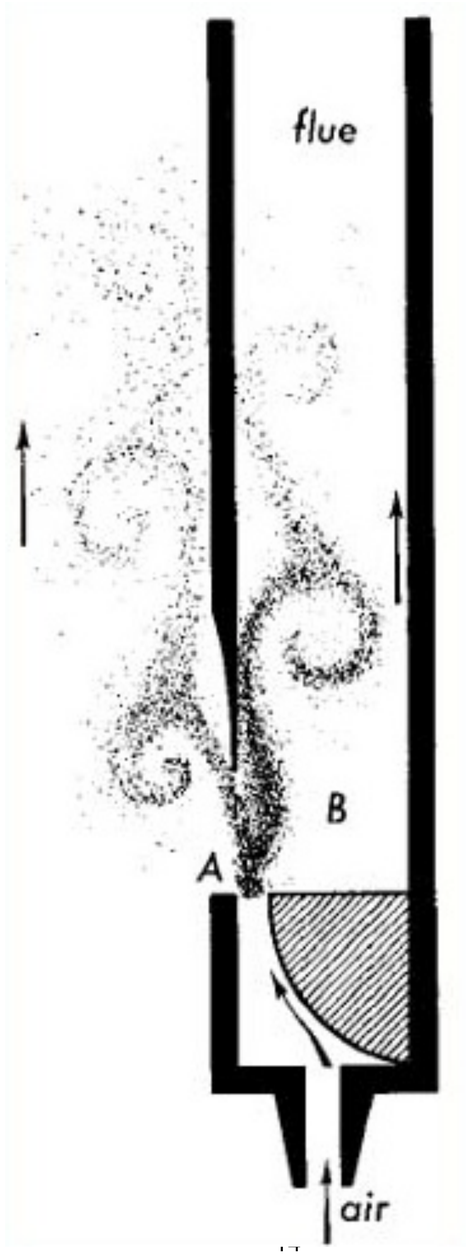
(air molecule displacements)

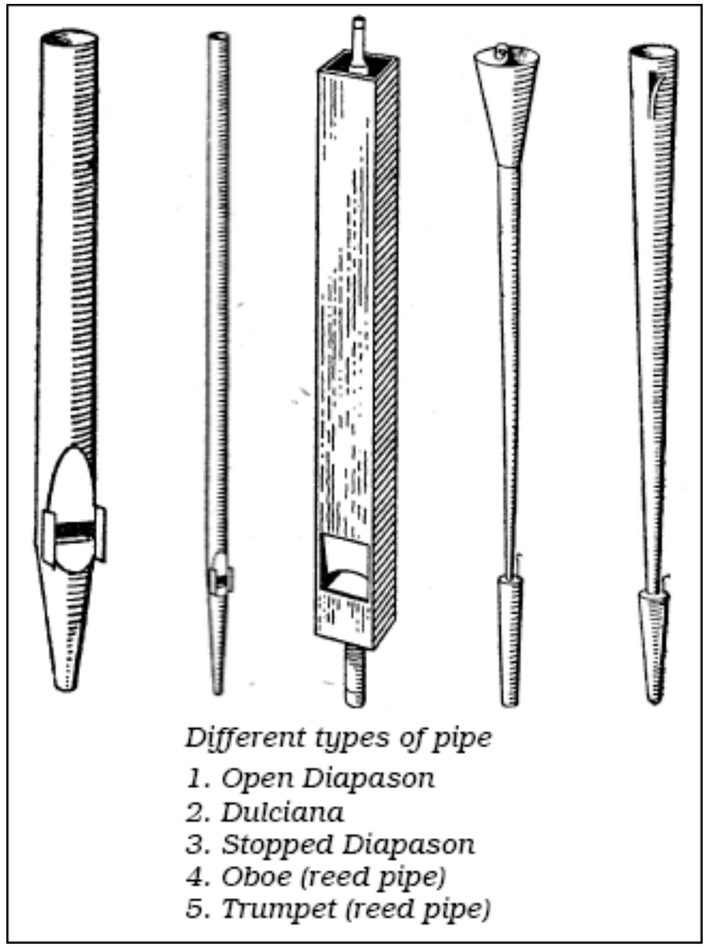
Excitations produced by an oscillating air stream or a vibrating reed





Flue-organ pipe

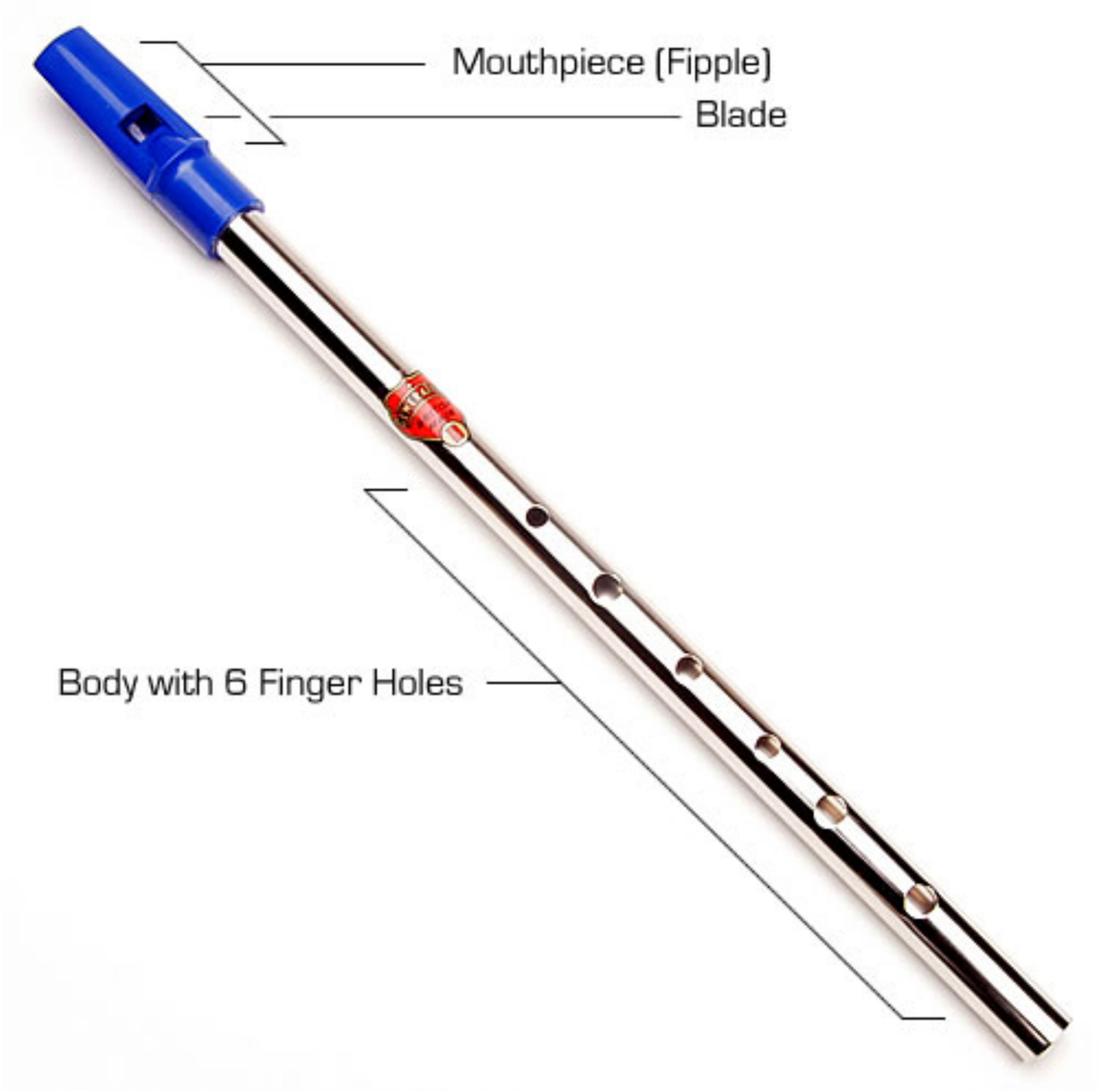




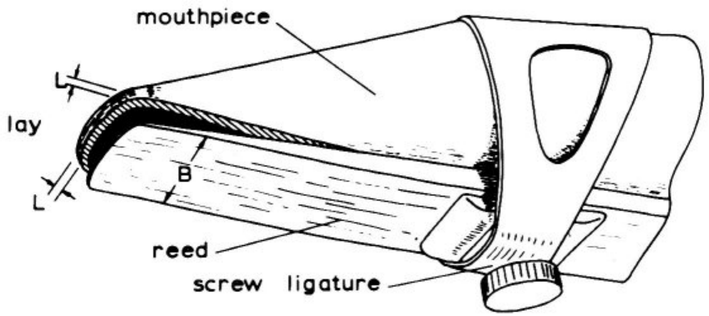
Different types of pipe

1. *Open Diapason*
2. *Dulciana*
3. *Stopped Diapason*
4. *Oboe (reed pipe)*
5. *Trumpet (reed pipe)*

Penny whistle



Clarinet


mouthpiece
lay
B
reed
screw
ligature


MouthPiece
Barrel Joint
Upper Joint
Ligature
Lower Joint
Bell