Friedrich-Alexander-Universität
Technische Fakultät

How sound is created by instruments

Alexander Luce

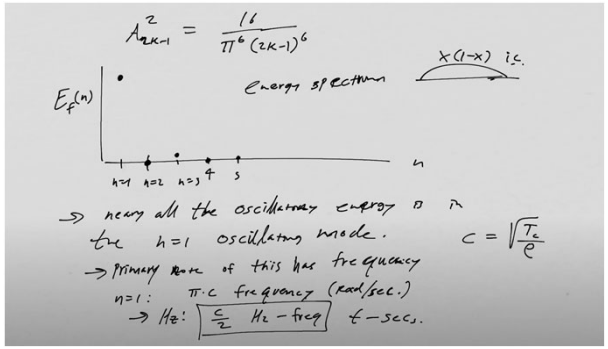
Sound and motion

- Sound is a pressure wave that propagates in air
- Excitation of the pressure wave by moving objects
- An oscillatory movement creates an oscillatory pressure wave

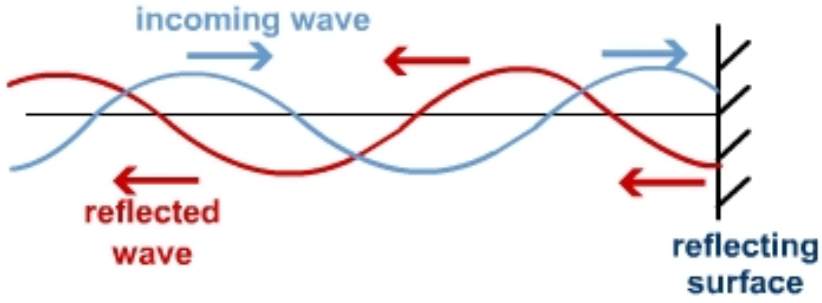
https://youtu.be/px3oVGXr4mo?t=9

Spatial Modes of instruments

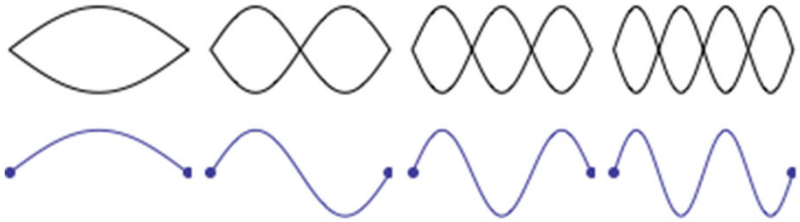
- In physics a standing wave, also known as a stationary wave, is a wave that oscillates in time but whose peak amplitude profile does not move in space
- A spatial mode/standing wave is created when a wave is reflected at a boundary in such a way that the reflected waves interfere constructively
- Frequency of the oscillation defined by material and geometry
- An instrument distributes the energy differently on the available modes



https://www.youtube.com/watch?v=37DxabEb4Ew&ab_channel=WilliamNesse



https://s-cool.co.uk/a-level/physics/progressive-waves/revise-it/standing-waves



https://www.acs.psu.edu/drussell/Demos/Pluck-Fourier/Pluck-Fourier.html

Lets get rid of a myth

This is **not** how strings move

The phenomenon here is a camera artifact, the sc. rolling shutter effect

The artifact occurs when recording movement which is much faster than the camera shutter speed

(60Hz normal camera vs 440Hz A4)

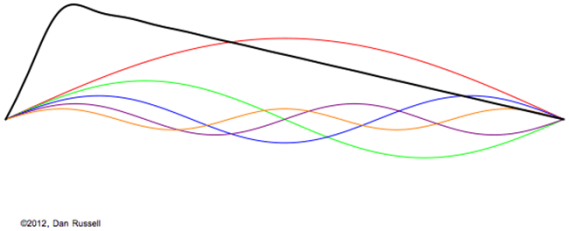
https://www.youtube.com/watch?v=XOCGb5ZGEV8&ab_channel=RuyMascar%C3%BAa

Excitation of spatial modes on a guitar string

Frequency components which are not in resonance will decay quickly

Only the harmonicas oscillate longer

The movement through air excites a pressure wave at the same frequency



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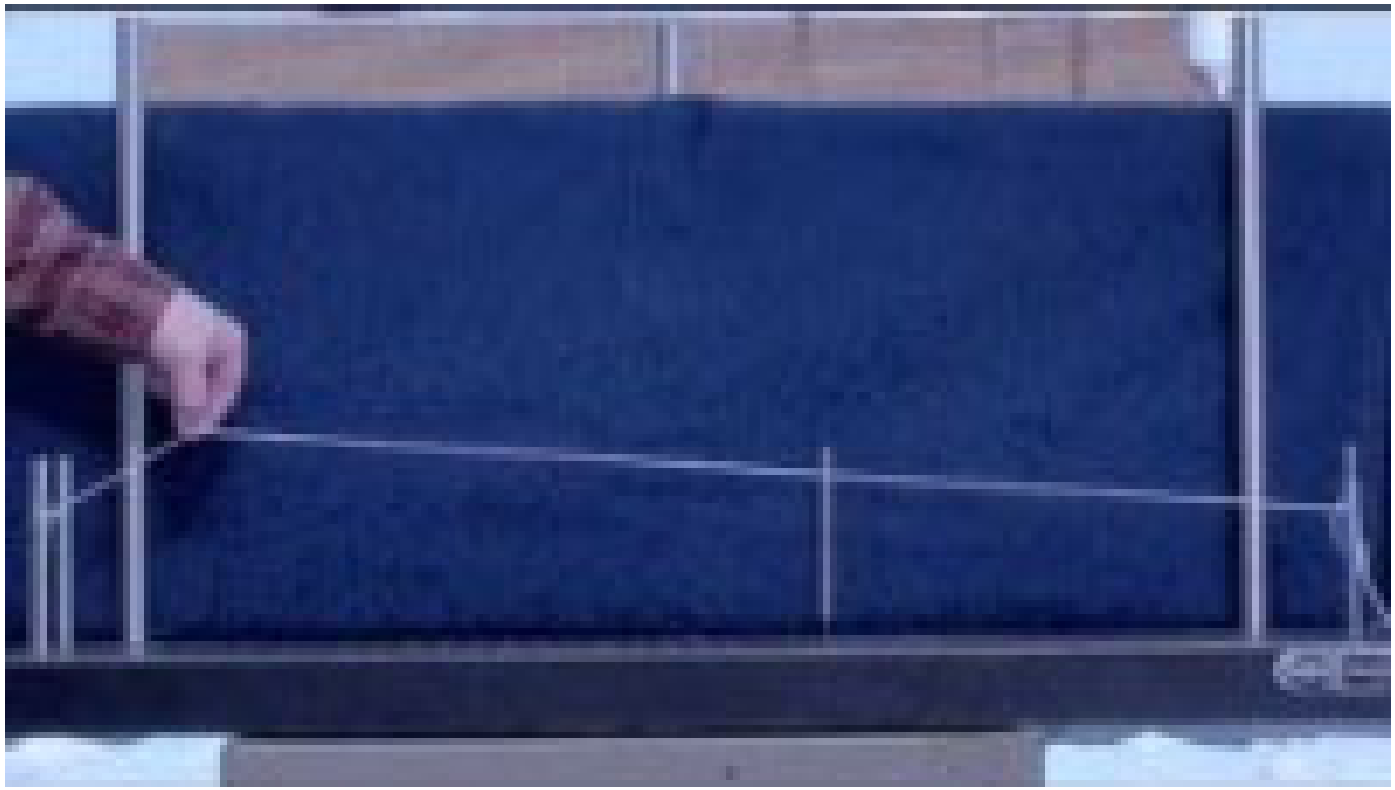
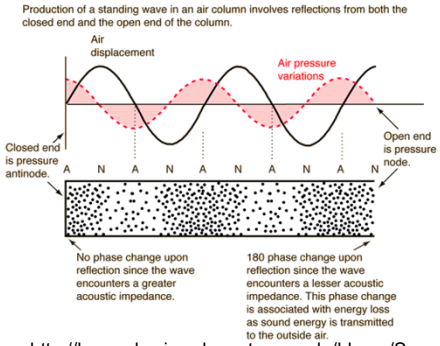


https://www.youtube.com/watch?v=_X72on6CSL0&ab_channel=DanRussell

The principle remains the same for other instruments

- Flute: traveling pressure wave



http://hyperphysics.phy-astr.gsu.edu/hbase/Sound/reflec.html

- Drums: Oscillating 2D surface

Modes of a cymbal

https://tenor.com/view/slow-motion-drums-gif-5470820

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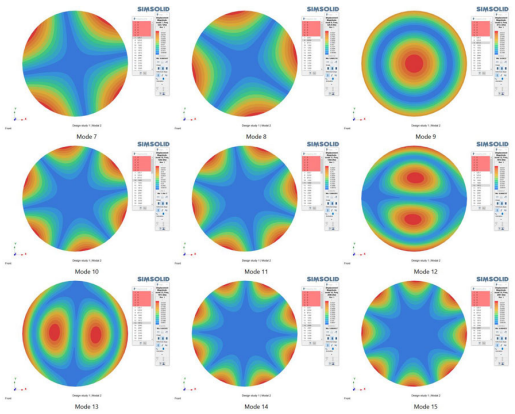

FEM Modes of a circular object

https://www.altair.com/newsroom/articles/High-frequency-modal-analysis-in-Altair-SimSolid

Standing wave in a 2D Rubens Tube

Most gas leaves the table at maximum amplitude of the pressure wave

The patterns emerge due to the superposition of the modes of the frequncy components of the music