11/12 Notes

Vibrations and Waves

What is the sound in a seashell?

Inside the shell there is a sound,
Mysterious to me.
How is it that the seashell can
Sound so much like the sea?

A seashell held up to your ear
Will block out background sound.
If you used a jar instead,
The same sound would be found.

Air molecules that bounce around
Are half of what you hear.
And half the sound is your own blood
That's rushing through your ear!

- A repeated motion, such as an acrobat swinging, is called a periodic motion.
- Any periodic motion that is the result of a restoring force is called **simple harmonic motion**.

Hooke's Law

- Spring force = -(spring constant x displacement)
- The negative sign signifies that the direction of the spring force is always opposite the mass's displacement.
- The value of the spring constant is a measure of the stiffness of the spring. The greater the k, the greater the force needed to stretch or compress the spring.
- SI units of k are N/m

Hooke's Law

Force (newtons)

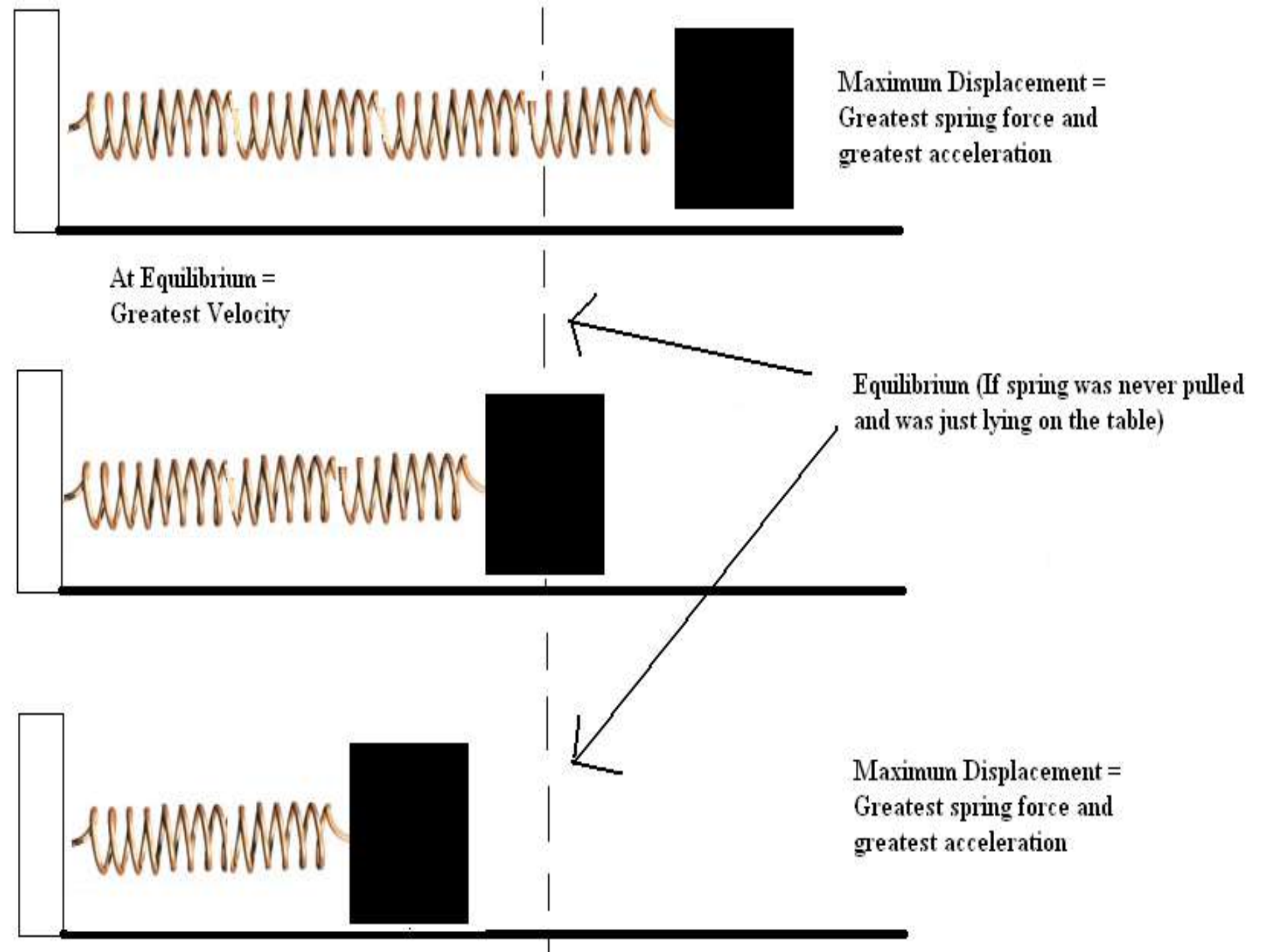
Extension or compression (meters)

$$F = -kx$$

Spring constant (newtons/meters)

Velocity and Acceleration

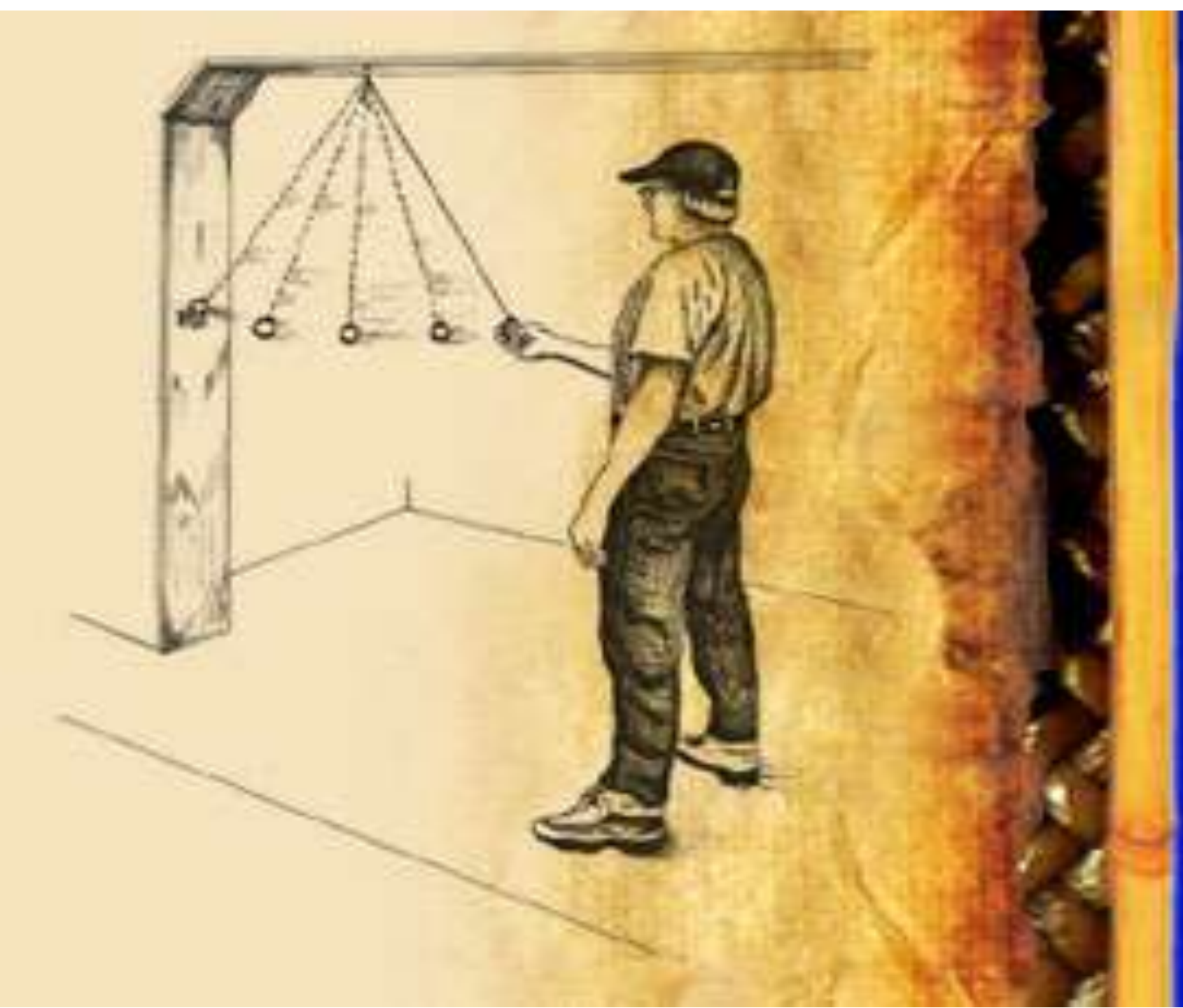
- Imagine you have a spring with a weight connected at the end. We lay the spring and weight flat on a table and pull the weight back and release.
- When the spring is at the equilibrium position, velocity reaches a maximum.
- At maximum displacement, the spring force and acceleration reach a maximum.


Maximum Displacement =
Greatest spring force and
greatest acceleration
At Equilibrium =
Greatest Velocity
Equilibrium (If spring was never pulled
and was just lying on the table)
Maximum Displacement =
Greatest spring force and
greatest acceleration

Simple Pendulum

- A simple pendulum consists of a mass called a bob, which is attached to a fixed string.
- When working with a simple pendulum, we assume the mass of the bob is concentrated at a point and the mass of the string is negligible.
- Also, we disregard friction and air resistance.

Pendulum Demo



- The **period** is the time it takes for a complete cycle.
- Period units = **seconds**
- Period = 1/Frequency

- The period depends on **string length** and free-fall acceleration (**gravity**).
- Period = $2\pi \sqrt{L/g}$

- Mass and amplitude don’t affect the period of a pendulum.
- This is similar to objects in free fall, which all have the same acceleration (gravity).

- Period of a mass spring system depends on **mass** and **spring constant**.
- Period = $2\pi \sqrt{m/k}$

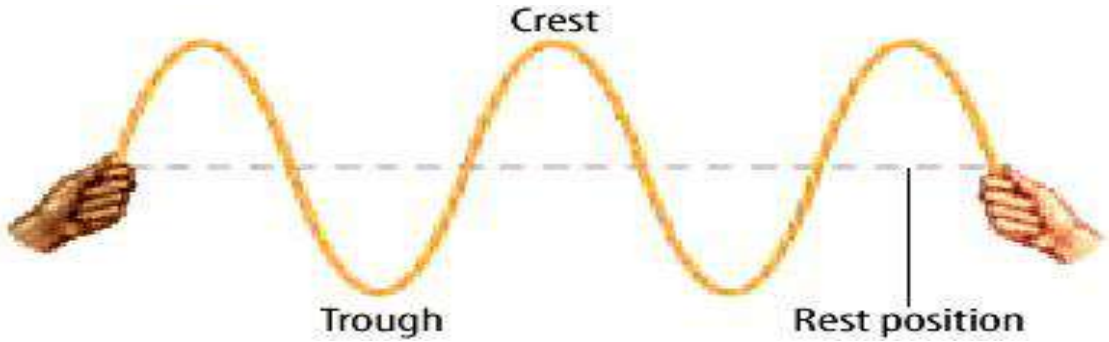
Wave Types

- A wave that consists of a single traveling pulse is called a pulse wave.
- If you have more than one wave, it is called a periodic wave.

Wave properties:

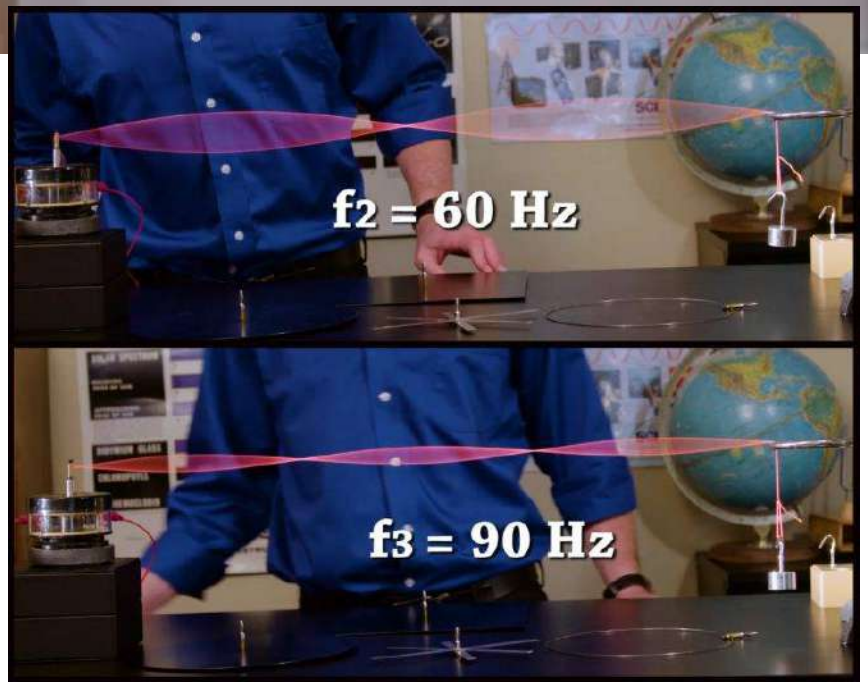
a. Wavelength – (meters)

Lambda λ

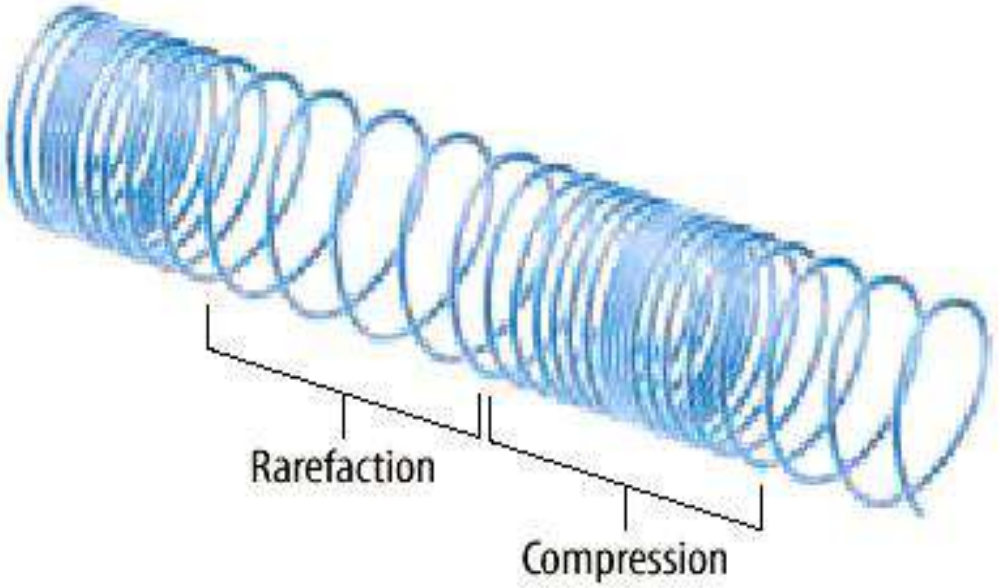


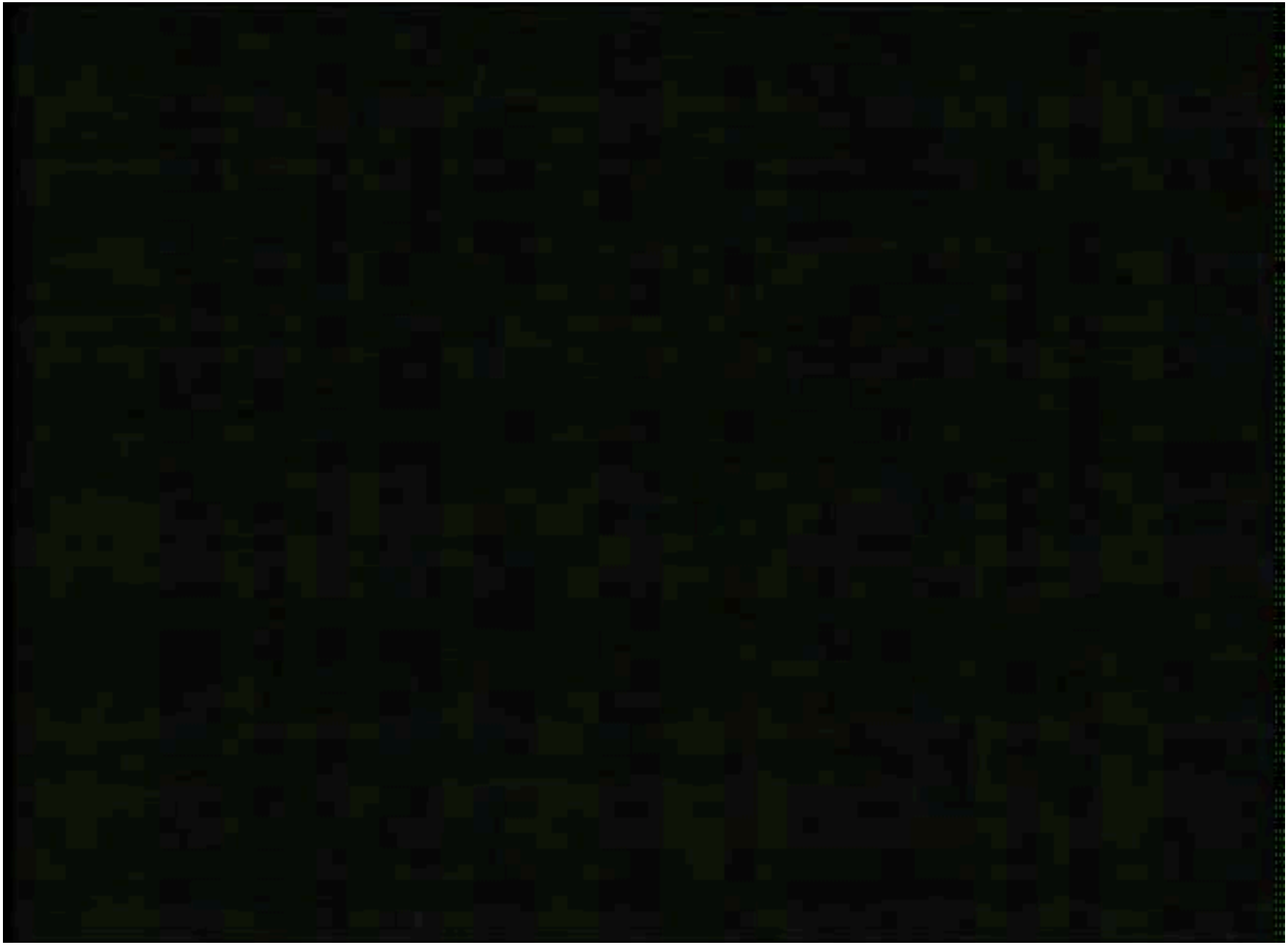
b. Frequency - # of waves that pass per second (Hertz Hz).

Wave Demos

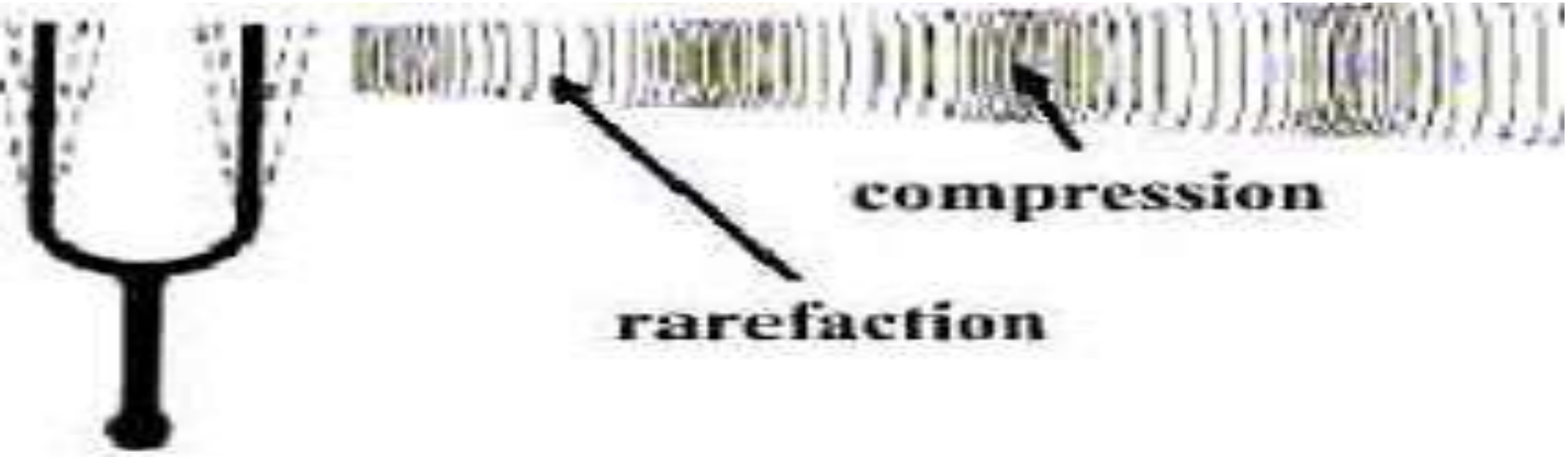


Compressional - Sound
v = 343 m/s
Must have a medium!! (air)



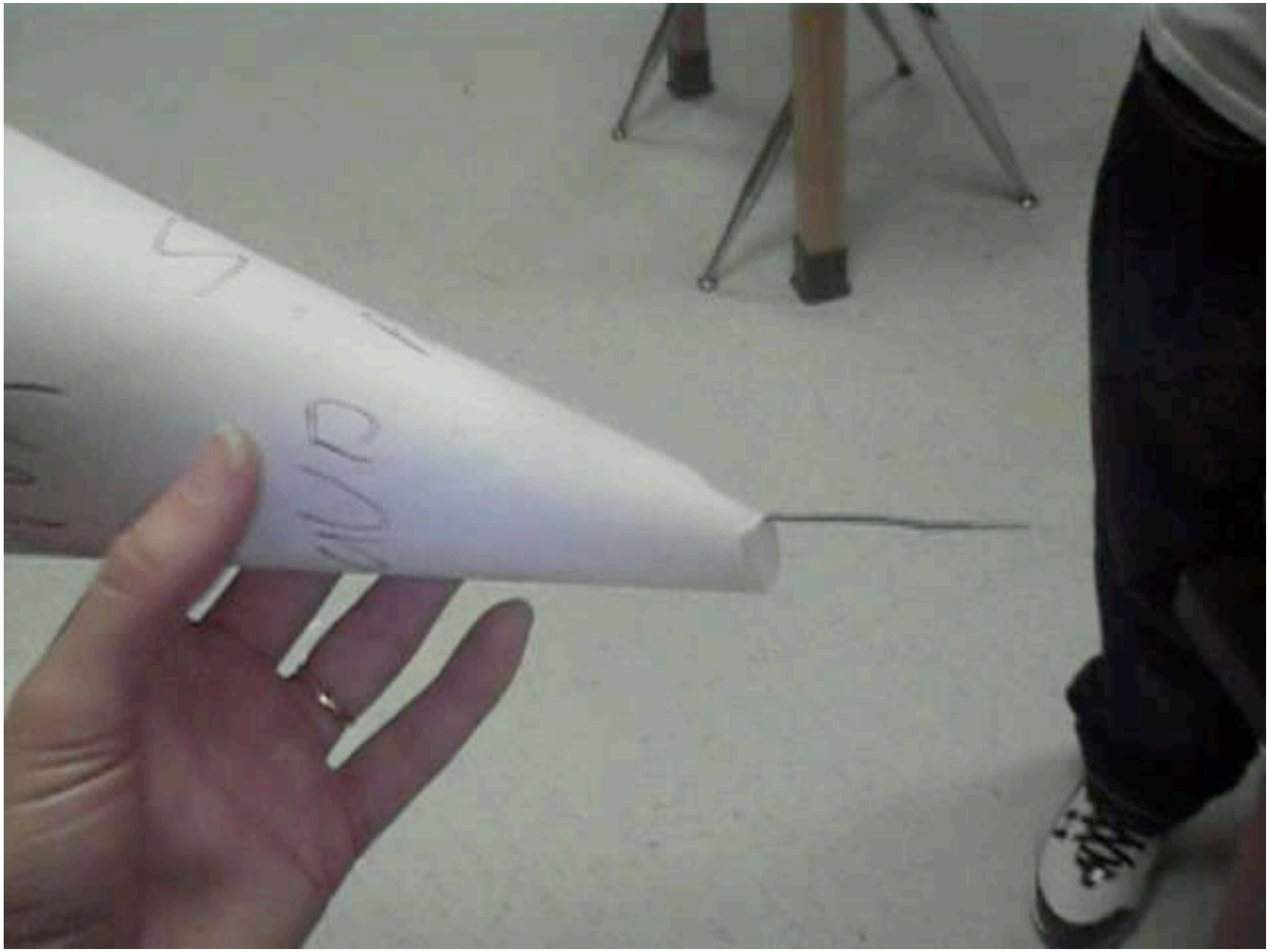


- A sound is a vibration.
- The vibrating causes the air molecules near the movement to be forced closer. This is called compression.
- As the vibration moves on, the density and air pressure becomes lower than normal and this is called rarefaction.



Mario Bros.

Musical Road Video



Demos –

Music Box

Thunder drum and mini drum

Chicken in a cup

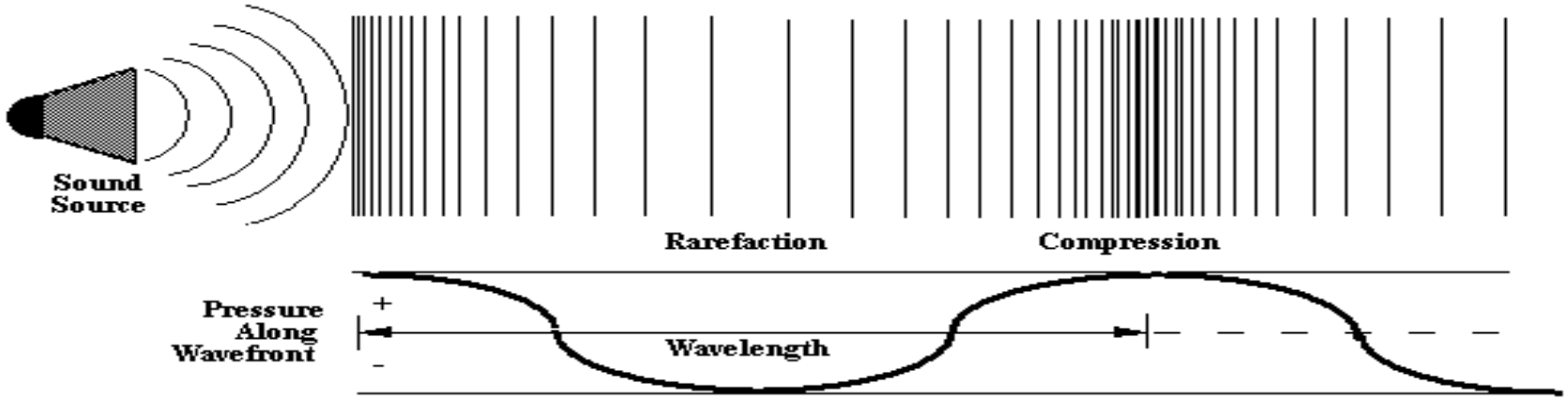
Sound Oscilloscope

Record Player

Spinning Sound

Straw Flute and Harmonica

- In sound waves, the vibrations are parallel and so it is a longitudinal wave.
- The crests of the sine curve correspond to compressions in the sound wave, and the troughs corresponds to rarefactions.



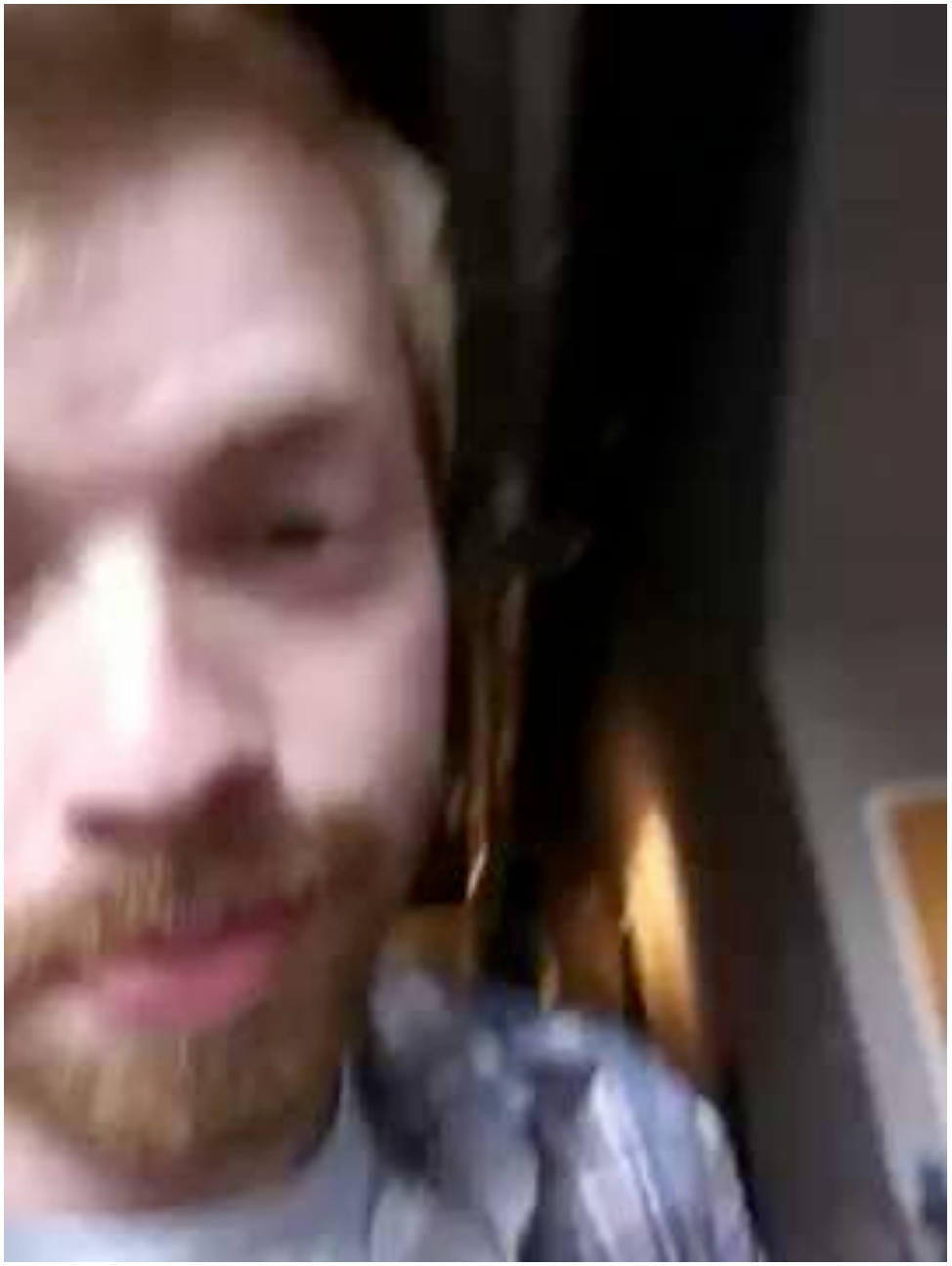
Rarefaction and Compression of a Sound Wave

- Sound waves that the average ear can hear, called audible sound waves, have frequencies between 20 and 20,000 Hz.
- Sound waves with frequencies less than 20 Hz are called infrasonic waves.
- Those above 20,000 Hz are called ultrasonic waves.

Demos

- Tone test app
- Speaker with Water

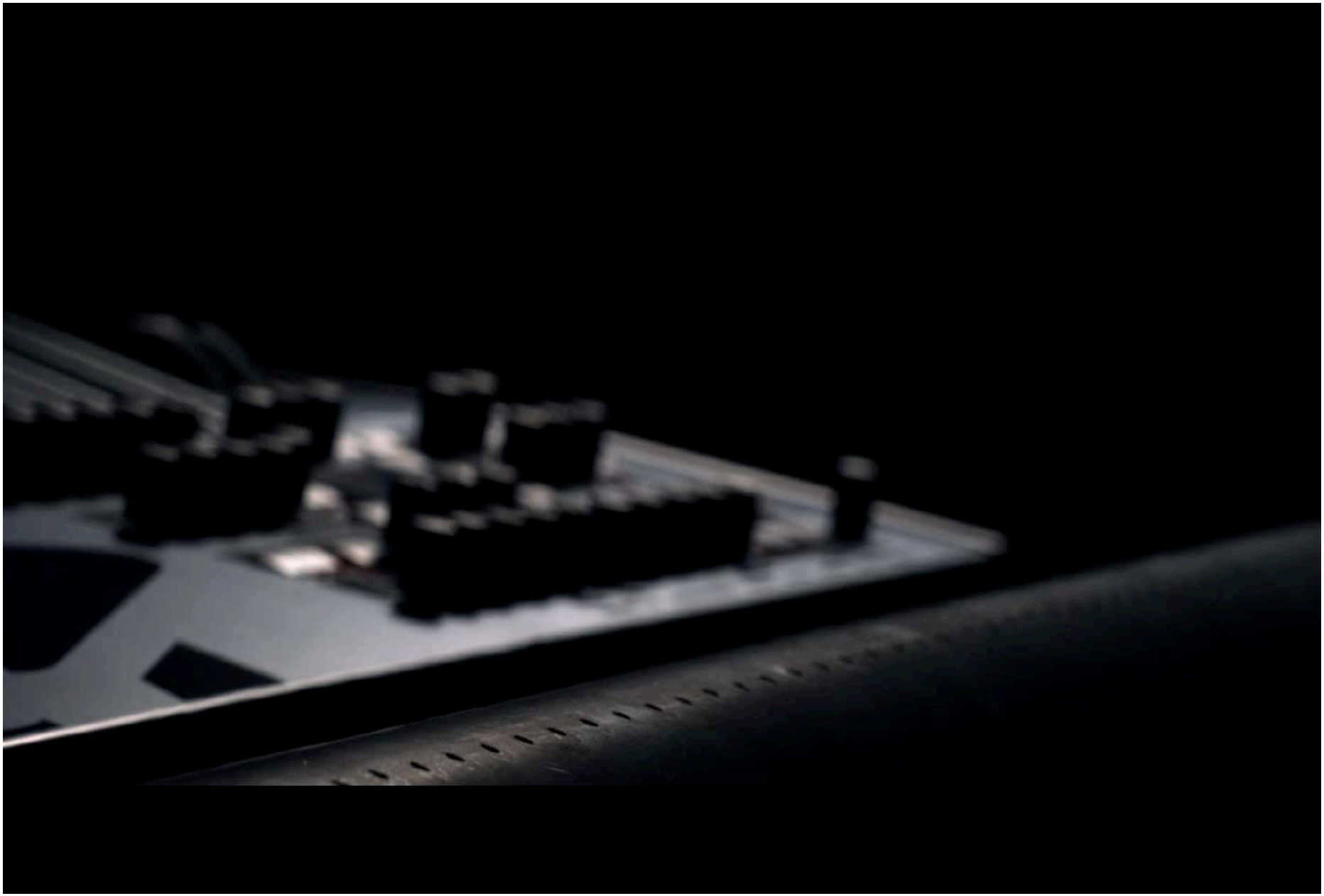
- Frequency determines the pitch.
- As the frequency increases, so does the pitch. **Video of Guitar Strings**
- Pitch is how high or low it sounds.
- Amplitude = Energy
- Uses for Ultrasonic waves:
- Ultrasound – See inside humans
- Dolphins – echolocation
- Ship Radar – Find other subs



Ruben's Tube

Demos

- Balloon with nut
- Horn with pvc pipe
- Wooden Flute
- Theremin
- Ruben’s Flame

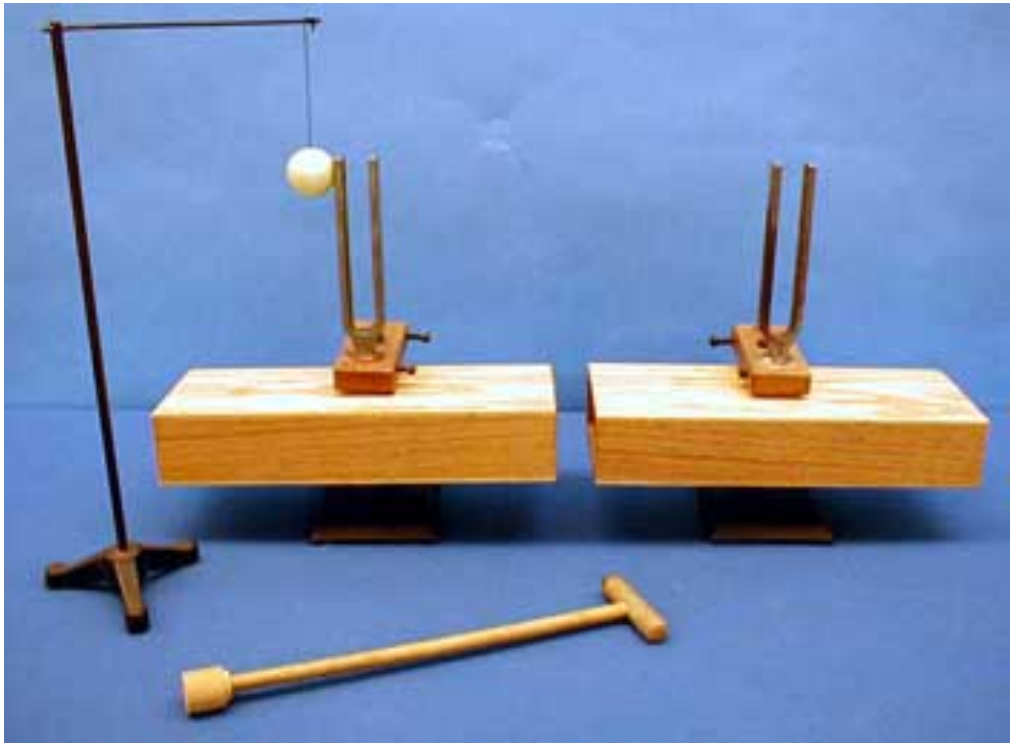


Velocity = wavelength x frequency

A wave is traveling at a speed of 18 m/s and its wavelength is 3 m. Calculate the wave frequency.

- Speed of waves depends on the medium and temperature.
- Solid particles respond more quickly to a disturbance than a gas particle because the molecules are closer together in a solid.
- Sound waves travel fastest in solids and slowest in gases.
- As temperature increases, particles collide more frequently which makes sound travel faster.

Resonance - When an object vibrates at it's ***natural frequency***.

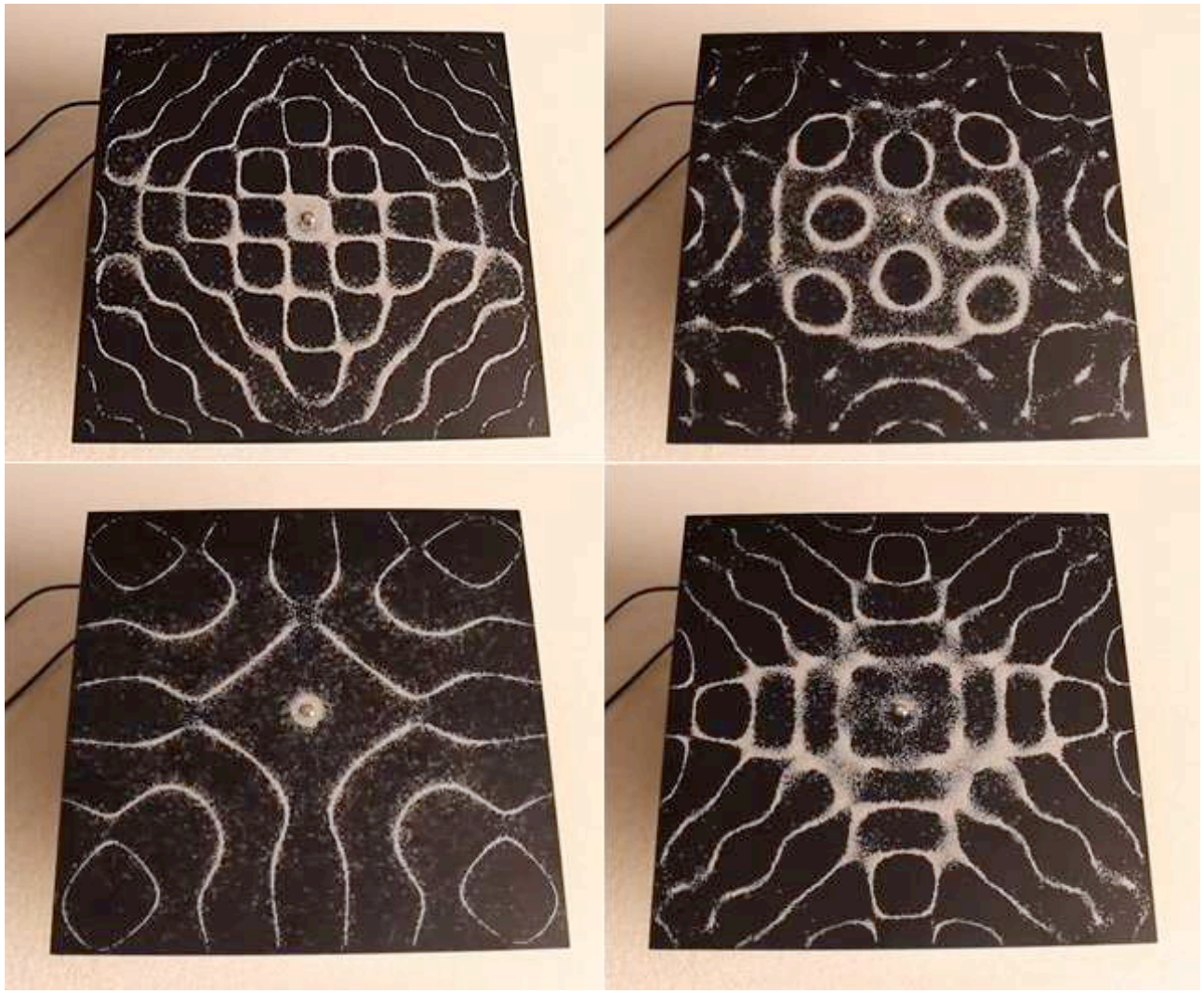


- All objects have natural frequencies.
- Every object will vibrate at a certain frequency.
- Resonance – a condition that exists when the frequency of a force applied to a system matches the natural frequency of vibration of the system.

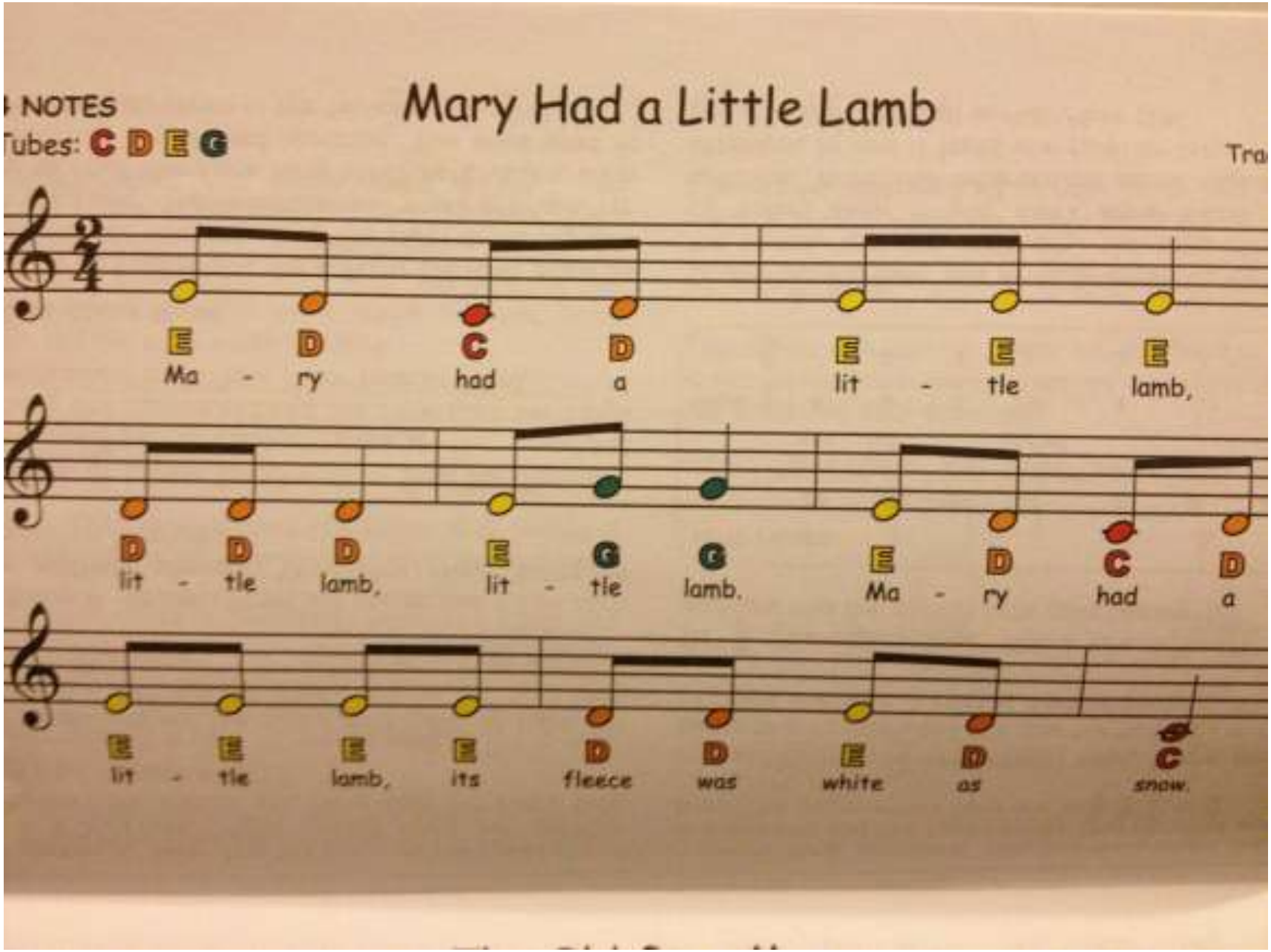
Tacoma Narrows

Salt on Speaker

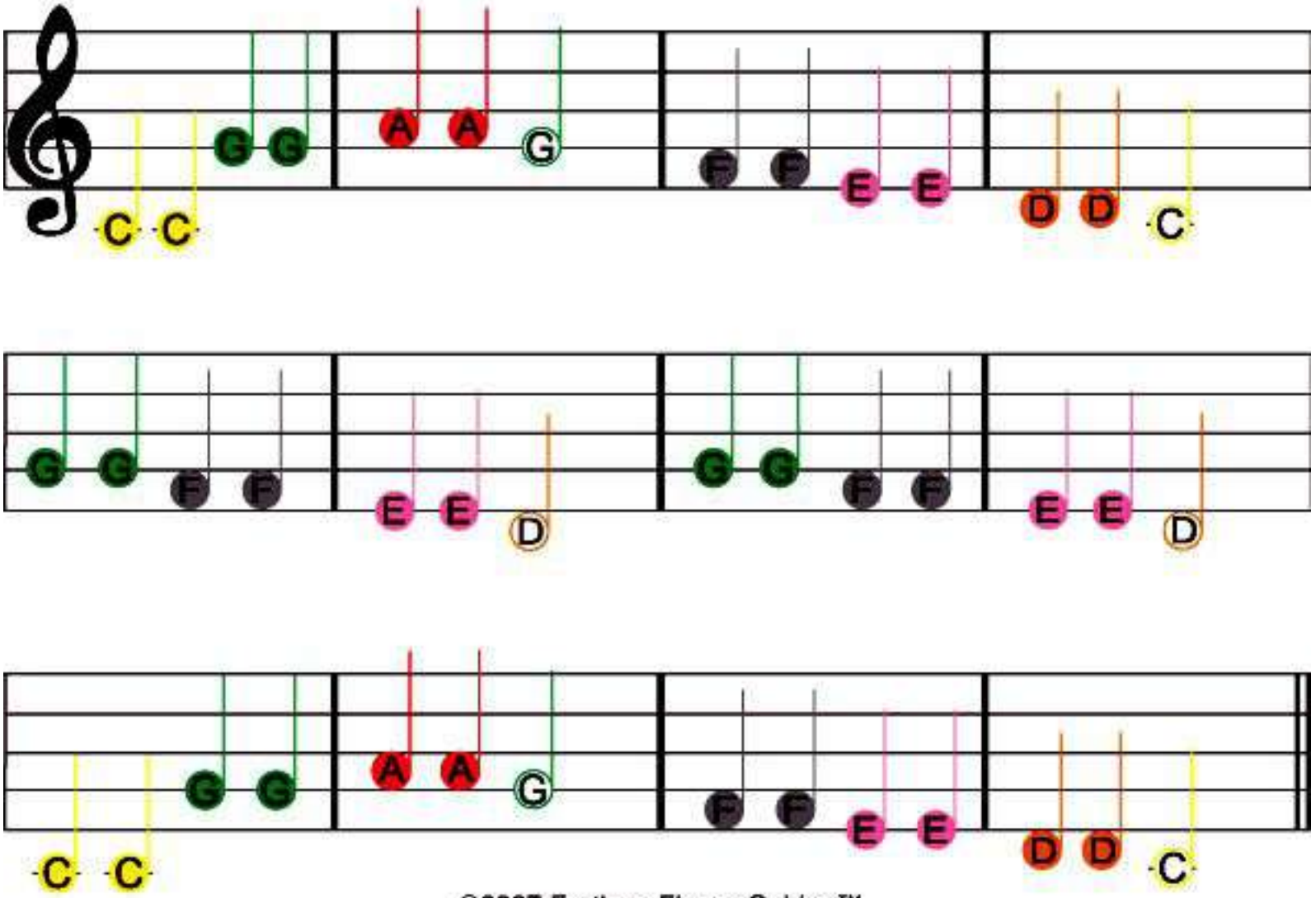
Speaker with attachments



Christmas Boomwhackers

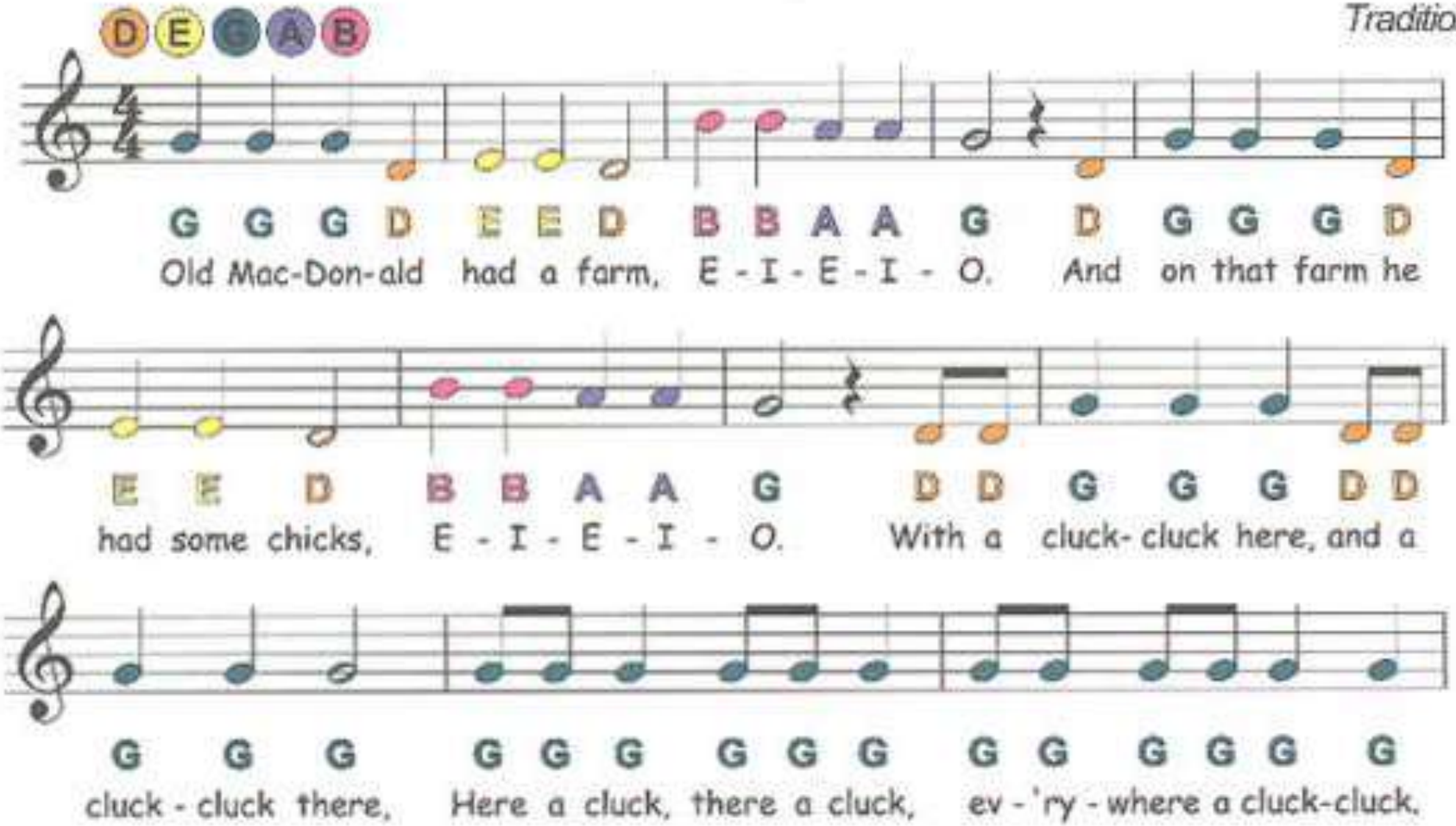

NOTES
Tubes: C D E G
Mary Had a Little Lamb
Tra
E D C D E E E
Ma - ry had a lit - tle lamb,
D D D E G G E D C D
lit - tle lamb, lit - tle lamb. Ma - ry had a
E E E E D D E D C
lit - tle lamb, its fleece was white as snow.

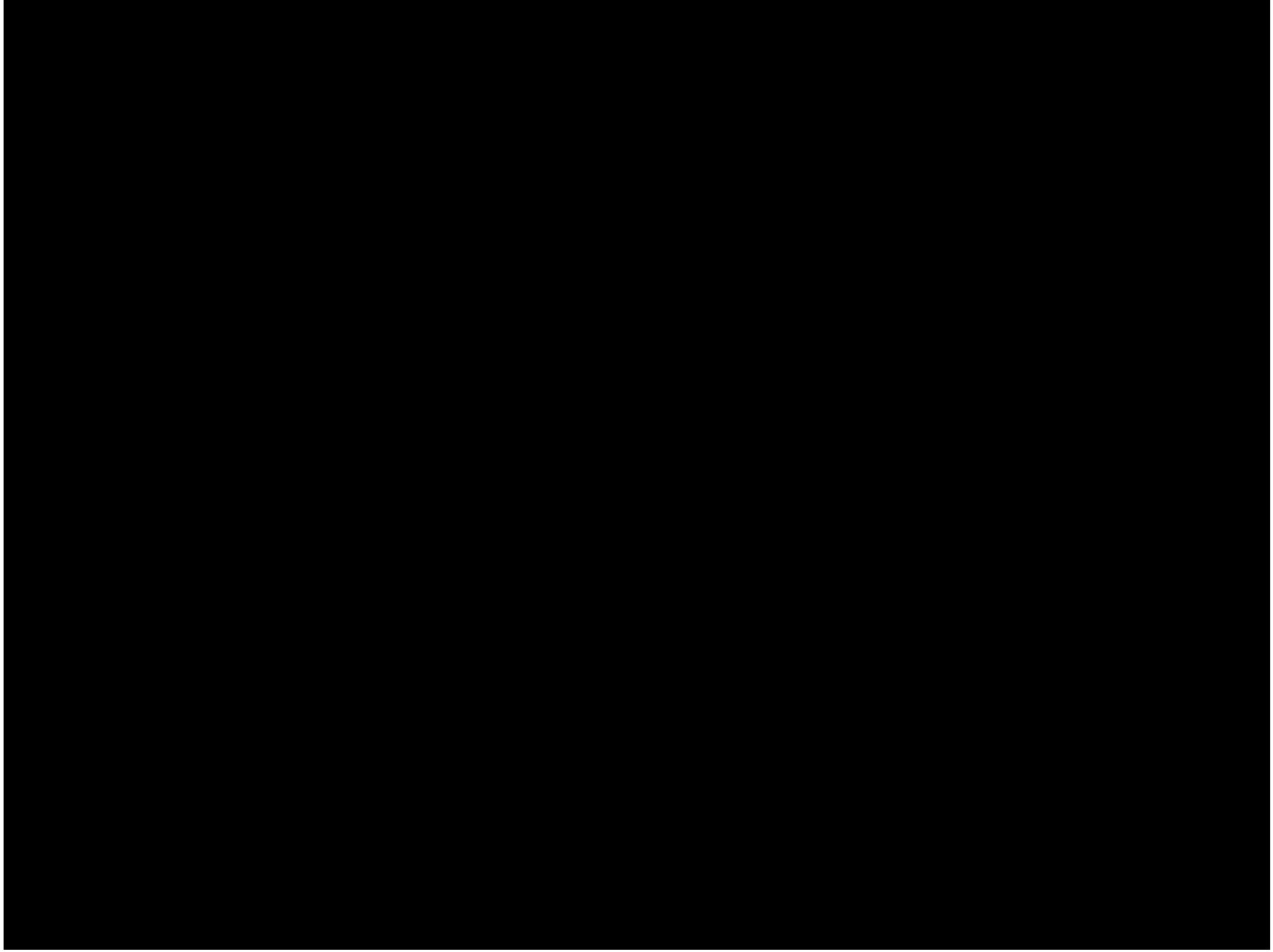
Twinkle Twinkle Little Star



Old MacDonald Had a Farm

Traditional





Resonance Demos

- Metal tube
- Resonance Bowl
- Tibetan Bowl
- Sticks
- Aluminum Rods
- Whirly toy

- Example 1 – Tacoma Narrows bridge. The wind blowing through the canyon matched the natural frequency of the bridge and caused the bridge to oscillate and eventually crumble.

- Example 2
- A kid on a swing, pumps their legs at the same frequency each time to cause them to swing higher each time. They are matching the natural frequency of the swing.

Example 3

- A wine glass has a natural frequency.
- A singer can sing at the same frequency and cause the glass to vibrate until it shatters.

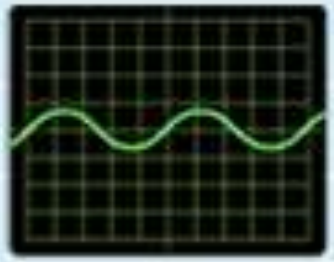
- Intensity – the rate at which energy flows through a unit of area perpendicular to the direction of wave motion.
- Intensity = Power / Area
- Area of a spherical wave = $4\pi r^2$

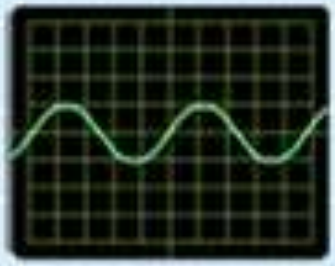
- Intensity and frequency determine which sounds are audible.
- Humans hear 20 to 20,000 Hz.
- The softest sound a human can hear is at a frequency of 1000 Hz and an intensity of 1×10^{-12} and is called the threshold of hearing.
- The loudest sound a human can tolerate has an intensity of 1 and is known as the threshold of pain.

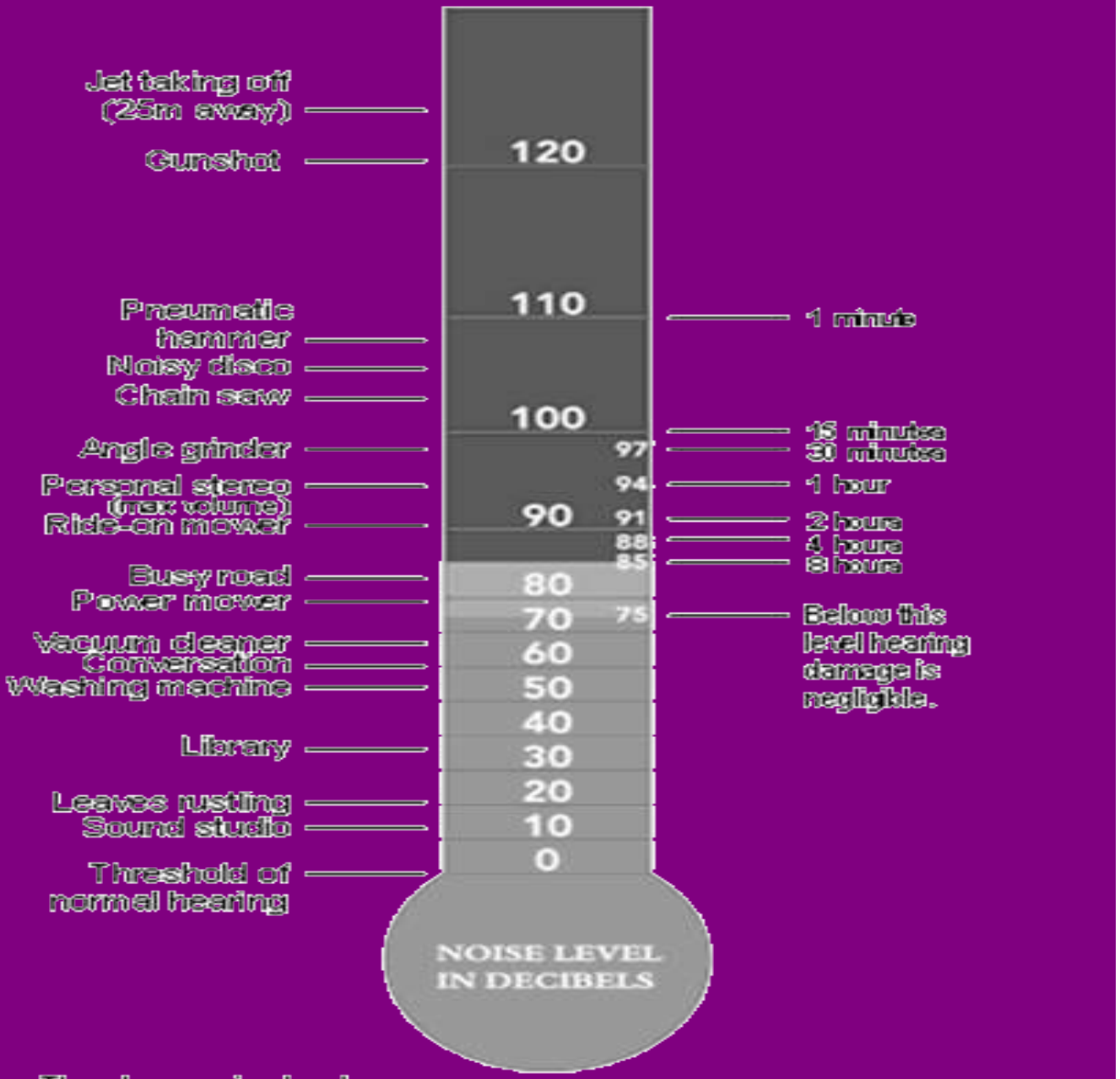
- Relative intensity is measured in decibels.
- The intensity of a wave determines the loudness.
- Relative intensity is the human perception of loudness.
- The decibel is a dimensionless unit.
- A difference in 10 db means the sound is twice as loud.

Some Common Decibel Levels

Sound	Decibel level
The softest sounds you can hear	0
Whisper	20
Purring cat	25
Normal conversation	60
Lawn mower, vaccum cleaner, truck traffic	80
Chain saw, snowmobile	100
Sandblaster, loud rock concert, automobile horn	115
Threshold of pain	120
Jet engine 30 m away	140
Rocket engine 50 m away	200







The above noise levels are approximate and should only be taken as a guide

- When an isolated guitar string is held tight and plucked, hardly any sound is heard.
- When the same string is placed on a guitar and plucked, the intensity of the sound increases dramatically. This is called forced resonance.
- The vibrating of the strings of a guitar force the bridge of the guitar to vibrate.
- The forced vibrations are called sympathetic vibrations.

Chapter 12-3

Harmonics

- The fundamental frequency is the lowest possible frequency of a standing wave.
- The series of frequencies of a standing wave are called the harmonic series.

- Frequency = harmonic number x (speed / 2 Length)
- $f = n\ (v/2L)$

- When a guitar player presses down on a guitar string at any point, that point becomes a node and only a portion of the string vibrates.
- As a result, a single string can be used to create a variety of fundamental frequencies.
- L in the previous equation would represent the portion of the string that was vibrating.

- Standing waves can also be set up in a tube of air and not just on a string.
- Harmonic series of a pipe if both ends are open is different on a pipe if only one end is open.

- Both ends open:
- Frequency = harmonic number x (speed/2L)
- $f = n(v/2L)$
- One end is closed:
- Frequency = harmonic number x (speed/4L)
- $f = n(v/4L)$

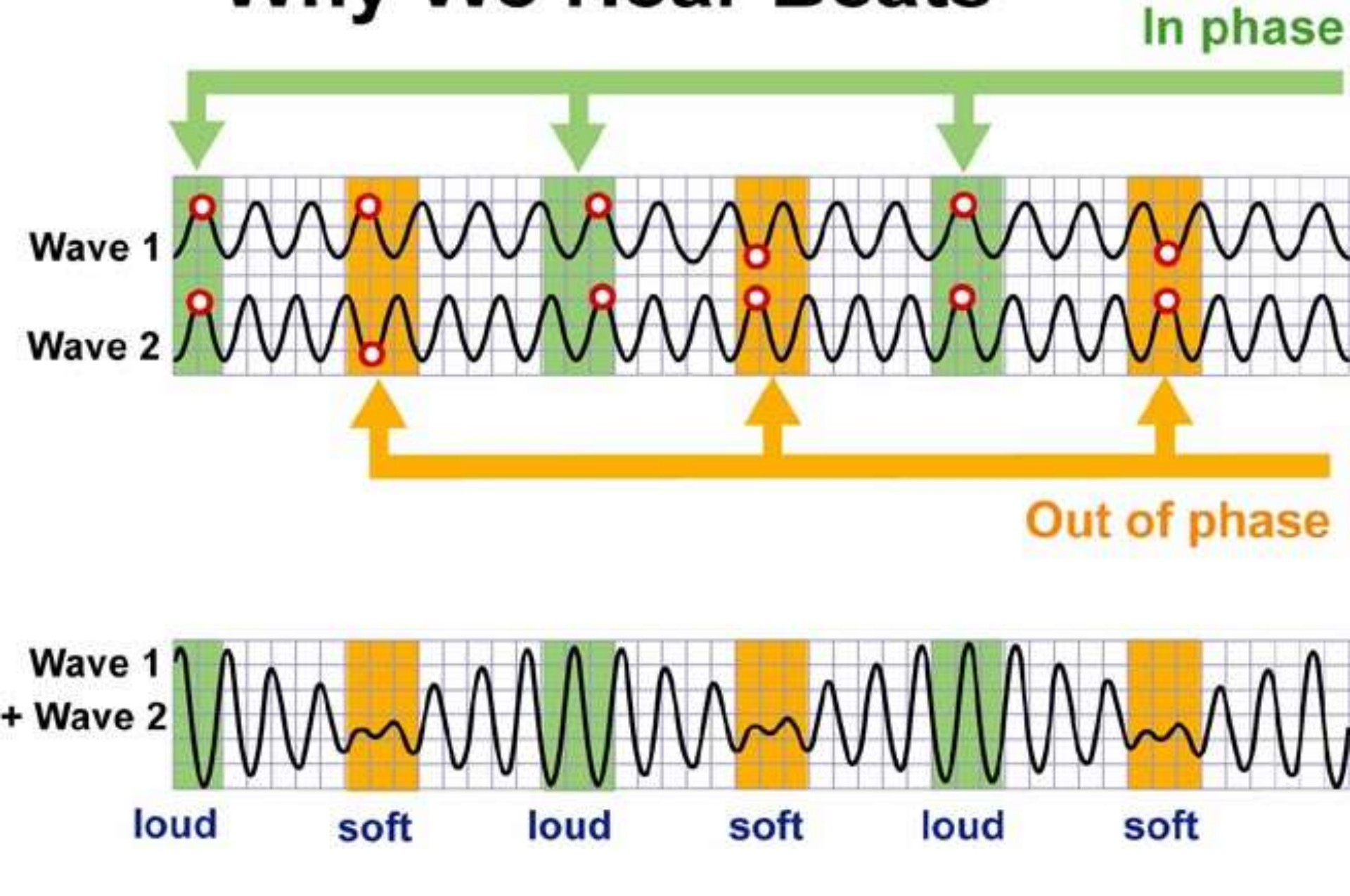
- In music, the mixture of harmonics that produces the characteristic sound of an instrument is referred to as the spectrum of sound, which results in a response in the listener called sound quality or timbre.

- When two waves of the same frequency interact, you get either constructive or destructive interference.
- If waves are opposite to each other they are said to be out of phase and destructive interference occurs. No sound is heard.
- If waves match up it is in phase and constructive interference occurs. The sound gets louder
- However, if waves with slightly different frequencies interact, a variation creates a soft to loud sound called beat.

440 hz and 441 hz

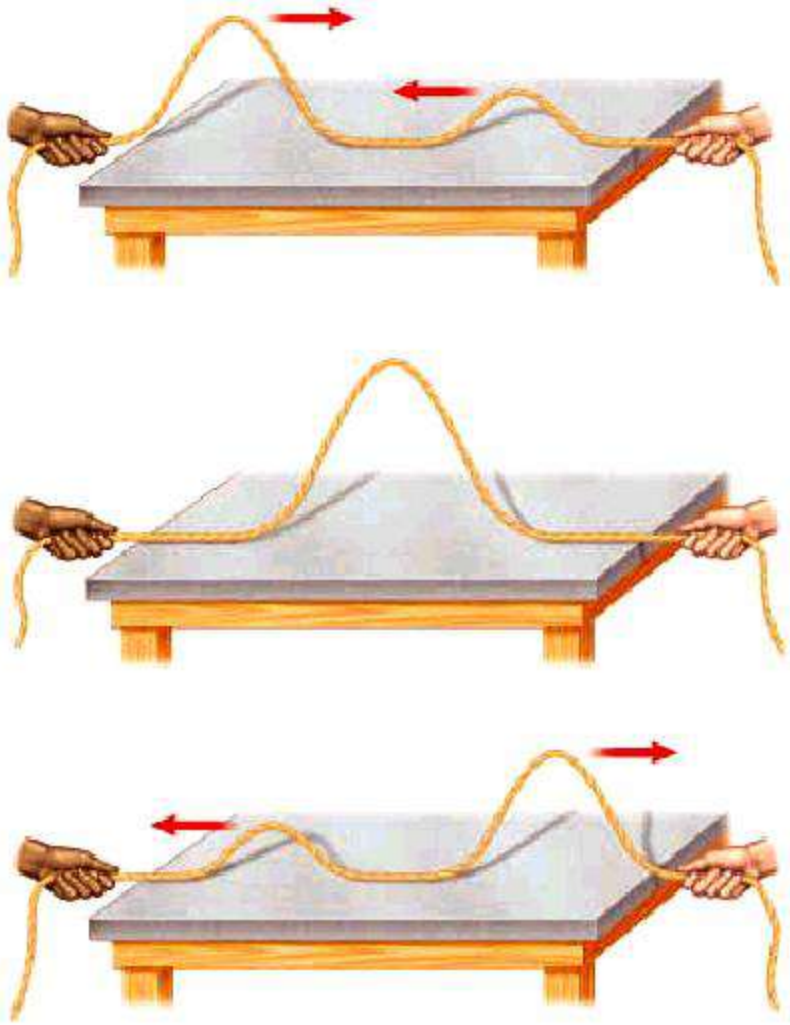
- http://onlinetonegenerator.com/

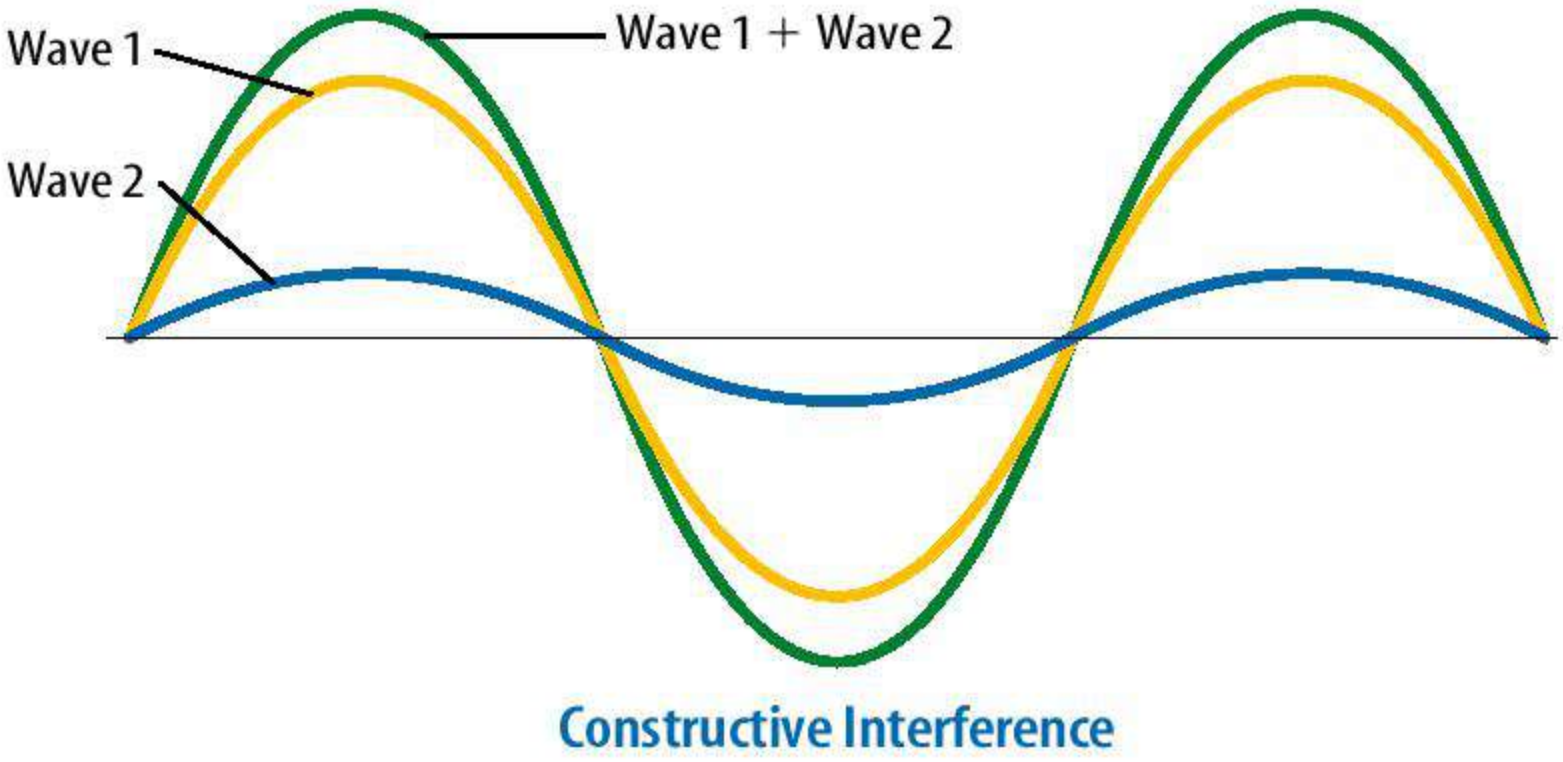
Why We Hear Beats



Interference

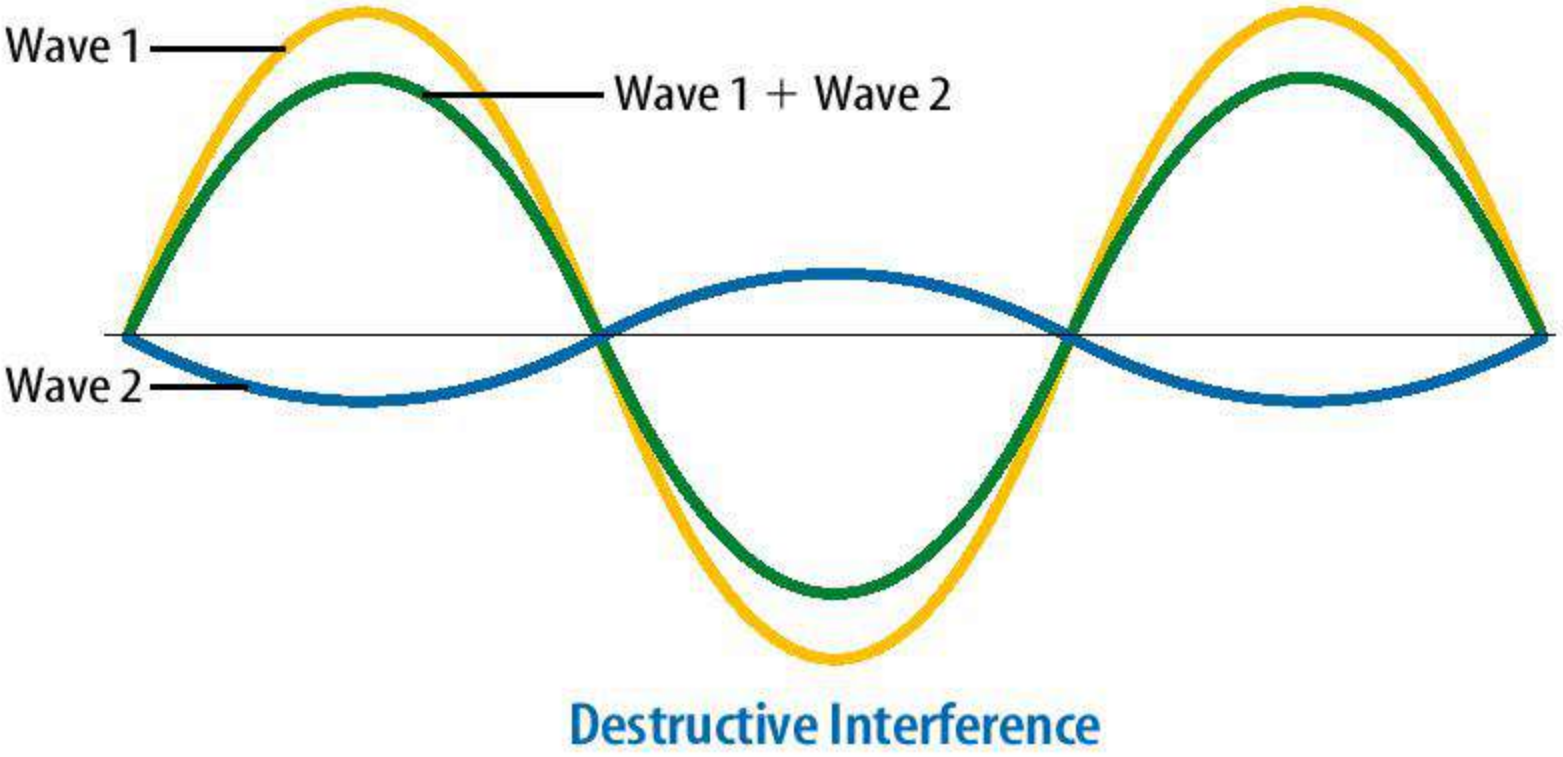
- two waves combine to form a new wave.





1) Constructive (in phase)

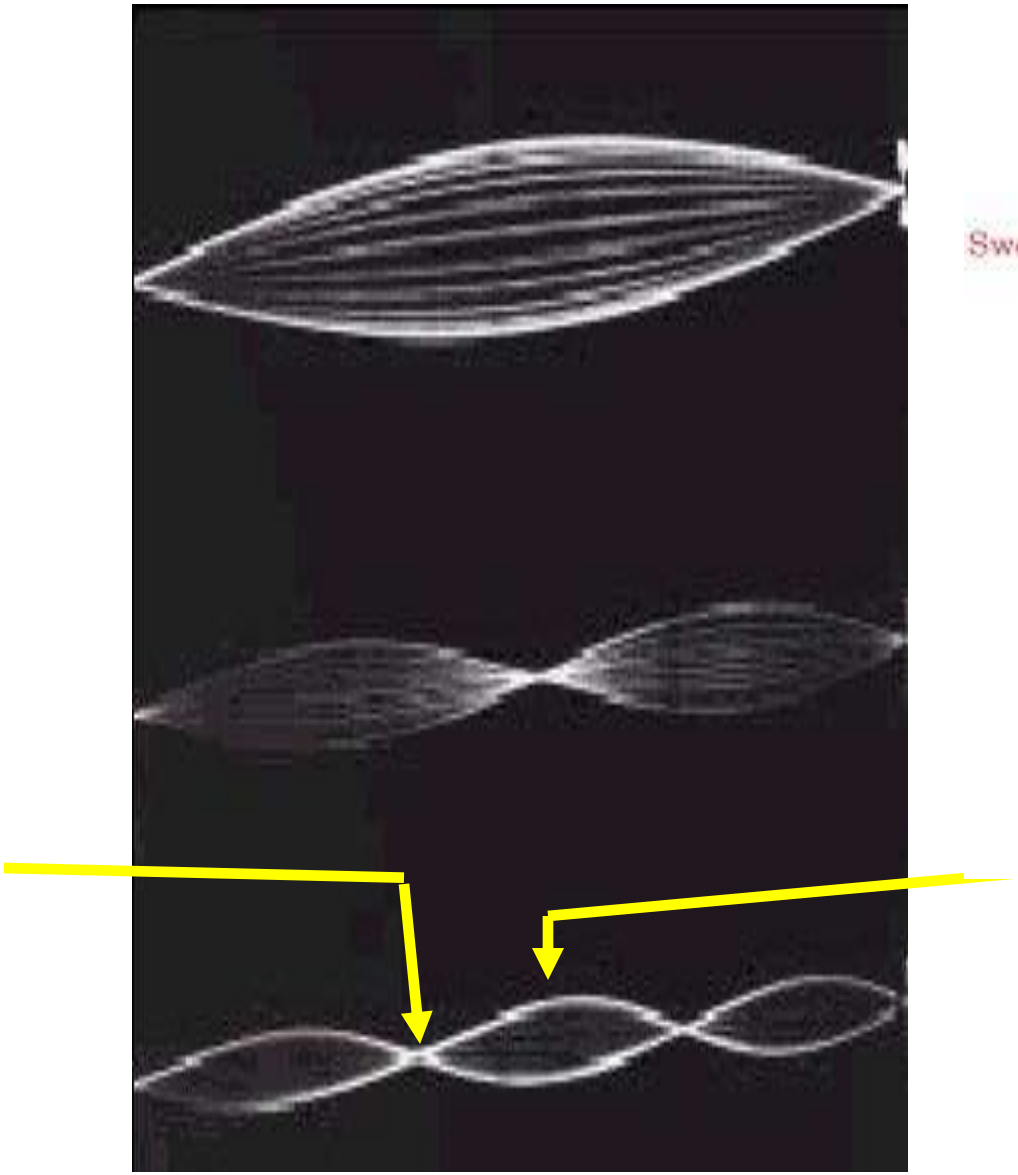
Sound waves that constructively interfere are louder

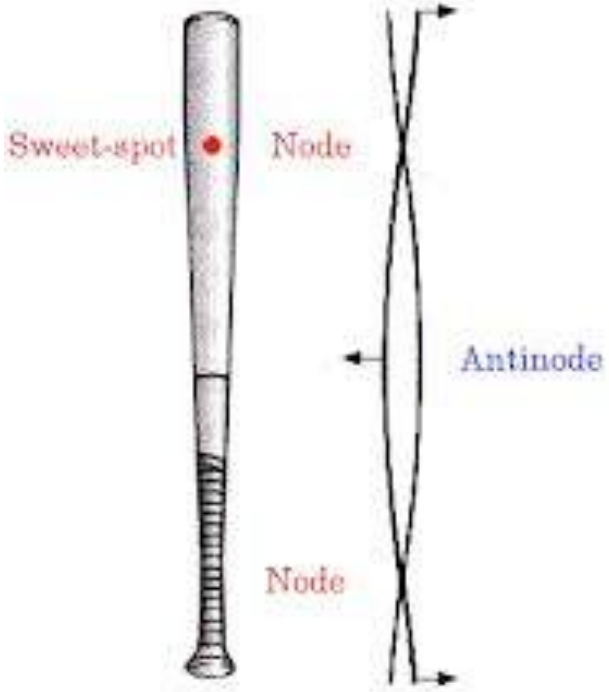


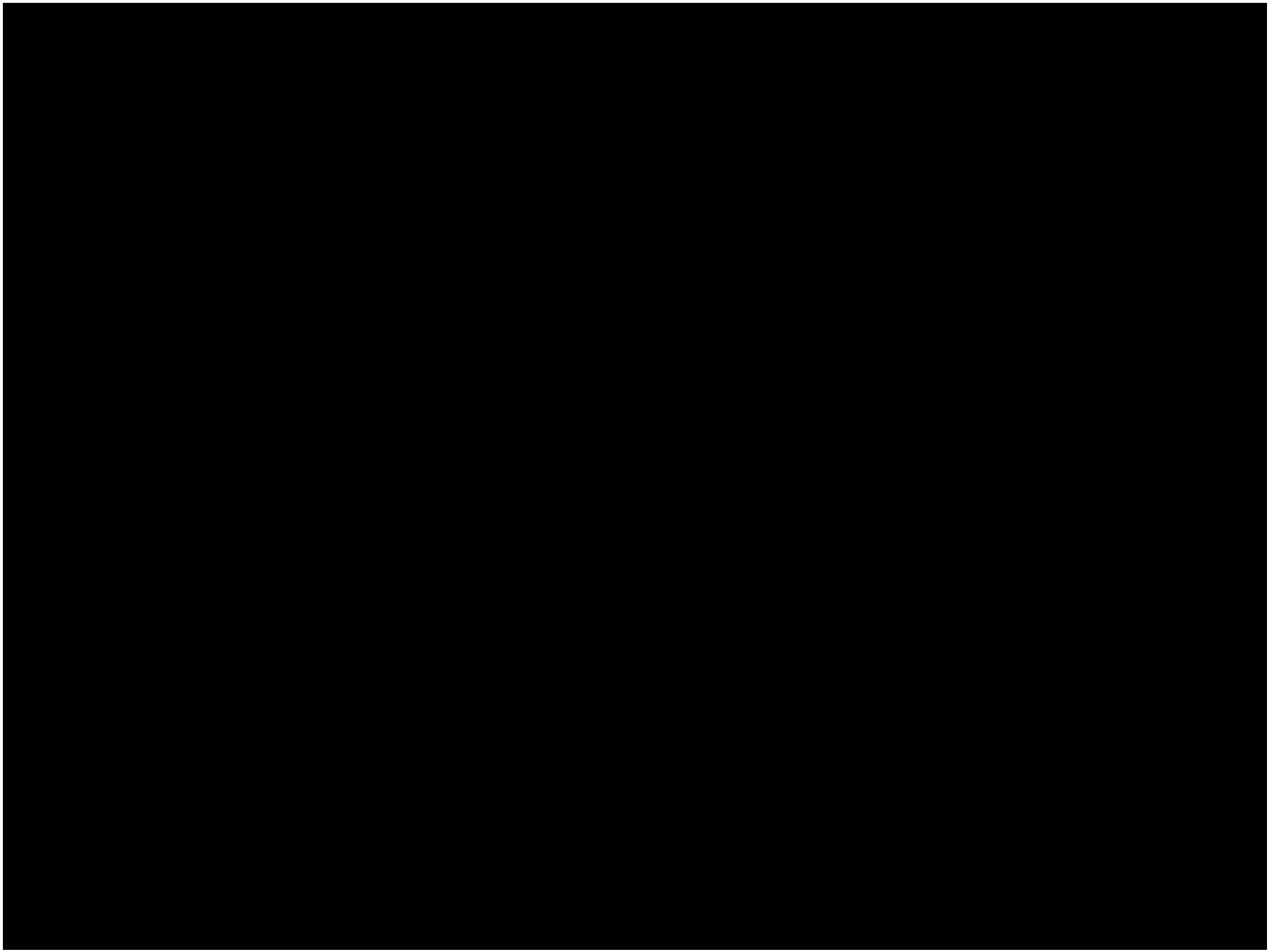
2) Destructive (out of phase)

Sound waves that destructively interfere are not as loud

Standing wave Demos and Video







Uses of sound waves

a. Acoustics – the study of sound.

Soft materials dampen sound; hard materials reflect it (echoes and reverberations).

b. SONAR – Sound Navigation and Ranging (echolocation).

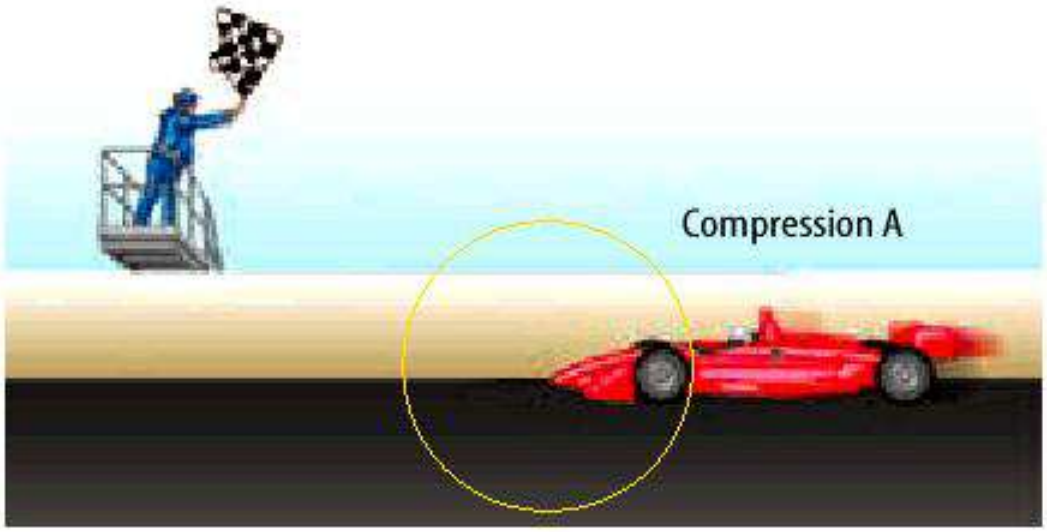
c. Ultrasound imaging

d. Kidney stones & gallstones.

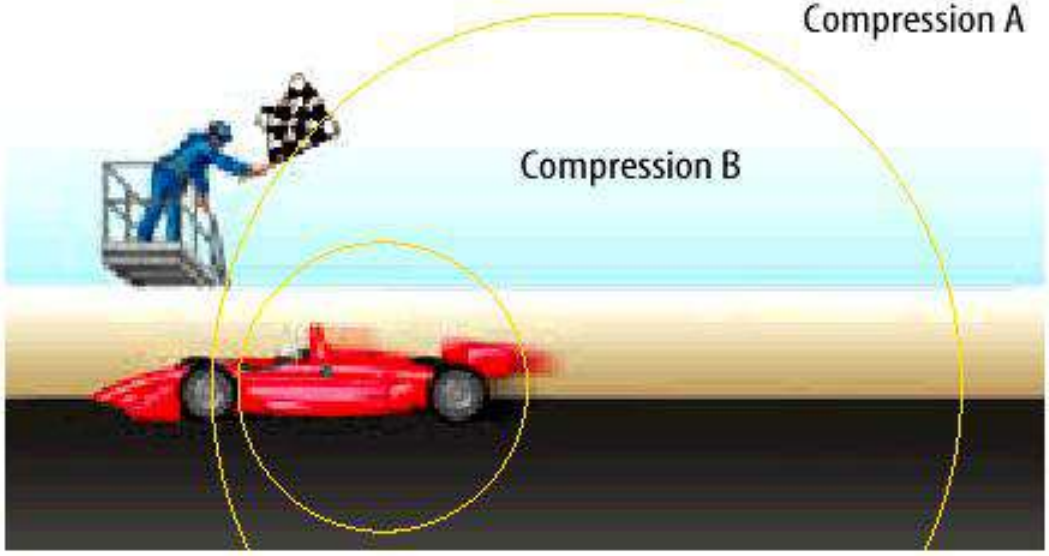
The Doppler Effect

– the change in pitch due to a ***moving wave source***.

The Doppler effect occurs when the source of a sound wave is moving relative to a listener.



A The race car creates compression A.



B The car is closer to the flagger when it creates compression B. Compressions A and B are closer together in front of the car, so the flagger hears a higher-pitched sound.

Doppler Effect Horn

Doppler Effect – Big Bang